WATER QUALITY INVENTORY AND MANAGEMENT PLAN

UPPER YELLOWSTONE RIVER BASIN
MONTANA

by

WATER QUALITY BUREAU
ENVIRONMENTAL SCIENCES DIVISION
Montana Department of Health and Environmental Sciences

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UPPER YELLOWSTONE BASIN, MONTANA

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FOR THE UPPER YELLOWSTONE RIVER BASIN

IN SOUTHWESTERN MONTANA

I. INTRODUCTION

This report presents information relative to water quality and water quality inventory and management in the Upper Yellowstone River Basin (Figure 1, Plate I). Also included is a description of the physical characteristics of the basin and a brief discussion of basin biological conditions. The objectives of this effort were to provide the state with water quality data and related information in order to:

1. determine the water quality characteristics of natural waters and wastewaters;

2. determine those factors, both natural and man-made, which affect the quality of water;

3. develop a management strategy for maintaining and enhancing the quality of waters in the basin;

4. and provide information needed to determine whether Montana's water quality standards are being met and will continue to be met.

The Upper Yellowstone River basin is the upper or western portion of the total Yellowstone River basin and is one of the sixteen basins designated by the State of Montana for the preparation of water quality management plans. The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) have directed states to prepare such plans as a part of a nation-wide program for controlling water pollution.

The general methodology used in this study was first the compilation and evaluation of existing water quality data and related information. Secondly, where information was deficient, field investigations and water and wastewater sampling and analyses were conducted to obtain needed information. This report does not present a detailed analysis or inventory of the basin's resources but summarizes water quality related information. As additional information becomes available, the Upper Yellowstone River basin water quality management plan will be revised and updated as a part of Montana's planning process.

Assistance in obtaining information for this report was obtained from a number of agencies and persons. The Montana

Department of Natural Resources and Conservation provided information on land use, water use, population and economy. The United States Geological Survey personnel provided unpublished water quality and discharge data on stations maintained by their agency. Federal waste discharge permit information was obtained from Mr. Richard T. Montgomery, U. S. Environmental Protection Agency, State Engineer for Montana. Weather data was obtained from the U. S. Department of Commerce Weather Bureau. Information relevant to municipal and industrial discharges within the basin was obtained from Mr. Alf Hulteng, Regional Public Health Engineer for eastern Montana. Thanks is also given to various individuals residing in the basin that supplied information pertinent to the study.

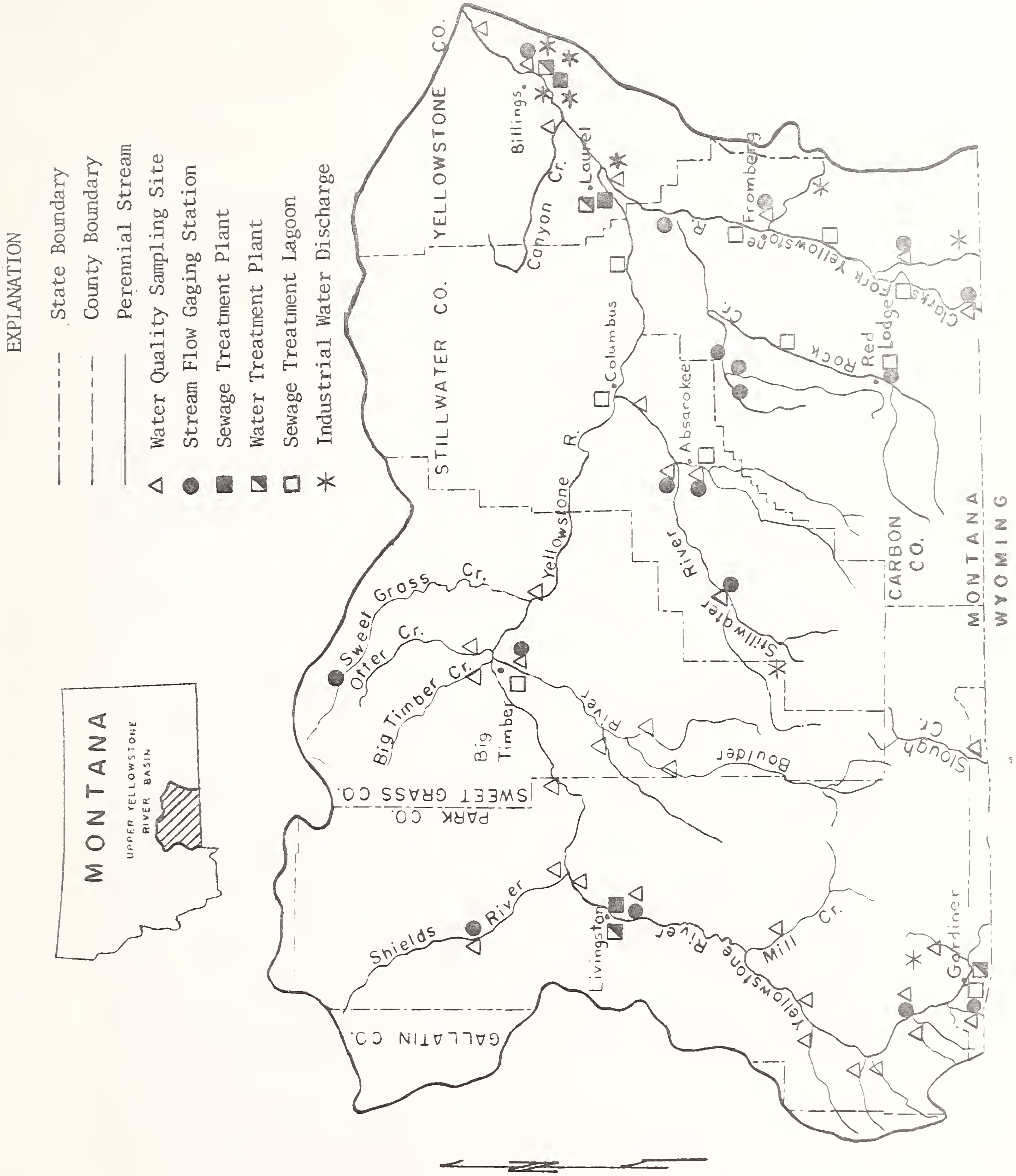


Figure 1. Sketch Map showing Upper Yellowstone River Basin

II. SUMMARY AND CONCLUSIONS

There are 21 municipal, 22 agricultural, and 9 industrial discharges in the Upper Yellowstone River Basin. In addition, a discharge occurs into Silvertip Creek, a tributary of the Clarks Fork Yellowstone River, from the Elk Basin Oil Field in northern Wyoming. Of the 21 municipal discharges, 4 are water treatment facilities, and the remaining 17 are sewage treatment facilities. Permits have been issued under the joint state-federal discharge permit system for 50 of these discharges. Permits for two of them are pending--one is a non-discharging lagoon and the other is the Livingston water treatment plant. Compliance schedules have been established for 12 sewage treatment facilities, 3 water treatment facilities, and 8 industrial discharges. Best practical treatment is required of industrial and municipal water treatment plants, and secondary treatment and any more stringent limitation necessary to meet water quality standards is required of municipal sewage treatment facilities by July 1, 1977. Construction is underway to provide secondary treatment for Billings, the major population center in the basin. Municipal facilities investments needed to achieve secondary levels of treatment for the remaining public sewage treatment facilities in the basin are estimated at approxmately $3.5 million.

Even with the application of best practical and secondary treatment to industrial and municipal discharges, all waters in the Upper Yellowstone River Basin will not meet state water quality standards. The Gardiner River will remain a water quality limited segment because of the constituents draining into the river from natural hot springs in Yellowstone National Park. High arsenic values are of particular concern. The upper Stillwater River drainage will remain a water quality limited segment due to high metals concentrations and acidity from acid mine drainage. The Clarks Fork of the Yellowstone River will also remain a water quality limited segment because of high sediment loads due to fragile soils, poor land conservation practices and continual overgrazing. The Yellowstone River from Laurel to Billings has been classified as water quality limited, largely due to the discharges from the Laurel and Billings sewage treatment plants, the wastewater discharges from three oil refineries, a sugar beet factory and a coal fired steam generating plant. There are also a number of non-point source sediment and oil problems in this reach of the Yellowstone River. A study entitled "Waste Load Allocation Investigation of the Yellowstone River in the Vicinity of Billings, Montana" has been undertaken to examine this problem.

Problems associated with high sediment concentrations are of major importance followed by oil, metals, and acid mine drainage.

A surveillance plan for continued monitoring of water quality in the Upper Yellowstone River Basin is described in this plan.

III. RELATED INVESTIGATIONS AND PLANS

BASIN-WIDE WATER QUALITY RELATED STUDIES

The Missouri Basin Comprehensive Framework Study (Ref. 1) broadly describes water quality and related resources of the entire Upper Missouri River Basin of which the Upper Yellowstone River Basin is a portion. A water quality study is currently being conducted by Montana State University on the Upper Yellowstone River to gain baseline data. Water chemistry and aquatic invertebrate distribution are being monitored.

EPA conducted a water quality survey of the waters of Yellowstone Park (Ref. 2)-May to August 1970. This includes the Soda Butte Survey - May to October 1969. A remote sensing study of sediment in the Clarks Fork Yellowstone River was prepared for the Bureau of Reclamation (Ref. 3). This study identified some of the more sediment laden streams in the Clarks Fork of the Yellowstone River sub-basin. The Bureau of Reclamation is currently conducting a total water management study for the entire Yellowstone basin. As a part of this study, the Water Quality Bureau has been contracted to run certain water quality parameters on water intakes from the Yellowstone River mainstem and several tributaries used for irrigation. The Water Resources Division of the Montana State Department of Natural Resources and Conservation is currently developing a framework plan for Montana. The Upper Yellowstone River Basin will be included as a part of this plan. The Department of Natural Resources and Conservation has contracted with the U. S. Geological Survey for water discharge monitoring and several of these sites are within the Upper Yellowstone River Basin. The Department of Natural Resources and Conservation has contracted with EPA to conduct an acid mine drainage study in the Cooke City area (Plate 1). The first part of this study is to determine the feasibility of abatement. The Department of Natural Resources and Conservation is currently preparing the feasibility portion.

The Old West Regional Commission has awarded a contract to the State of Montana to assess the impact of coal development on the water resources of eastern Montana. The lower portion of the Upper Yellowstone River Basin is included as part of the region under investigation. The Department of Natural Resources and Conservation is administering the contract and have funded several state agencies and universities for technical assistance on the project.

The United States Forest Service is conducting environmental surveys of the Custer and Gallatin National Forests. As a part of these surveys, some water quality data is being collected. The Montana State Department of Lands has initiated a study of saline seep problems in Montana. The surface water quality assessment has been contracted to the Montana State Department of Health and Environmental Sciences, Water Quality Bureau.

The State of Montana has requested the Missouri River Basin Commission to prepare a level B study in the Yellowstone River Basin. The aim of this study is to synthesize the available information concerning the conflicts between industrial and agricultural development, and related instream flow requirements (Ref. 19).

There have been a number of studies conducted in the Upper Yellowstone River basin as theses for graduate degrees at various universities. These studies, in part, provide some water quality information (Ref. 4,5,6,7,8, and 9). Two studies have been conducted on the Clarks Fork Yellowstone River in regards to the sediment problem (Ref. 3 and 10). One study indicated the practicability of using aerial color infrared photography and thermal infrared imagery in locating and identifying inflow of sediment-laden waters to the river. The other presented a comprehensive study of the sediment-erosion problem along with suggestions for control.

The U. S. Bureau of Recreation has been investigating the Yellowstone River from Gardiner to Pompeys Pillar. The potential for the Yellowstone in this reach coming under the Wild, Scenic and Recreational River Act is being considered.

The Montana Fish and Game Department has been investigating an area between the Stillwater and Boulder River drainages as it relates to mining activities. Some water quality data has been gathered, particularly in the Stillwater drainage (Ref. 11).

The Water Quality Bureau of the Montana State Department of Health and Environmental Sciences has initiated a waste load allocation study of the Yellowstone River in the highly developed Laurel-Billings area. Previous work has been done by the Department in regards to water pollution in the Yellowstone drainage (Ref. 16, 17 and 18).

BASIN-WIDE WASTE TREATMENT MANAGEMENT PLANS

The federal government established a grant program to municipalities to be administered by the Montana State Department of Health and Environmental Sciences. This grant program provided the municipalities with a percentage of the construction costs needed to update or establish a community sewage treatment facility including outfall and interceptor sewers. Priorities for these grants were established by the Montana State Department of Health and Environmental Sciences using a formula which follows federal guidelines. The City of Billings is the only municipality in the Upper Yellowstone River basin currently receiving a grant under this program. Any construction grants for sewage treatment facilities after July 1, 1974, will come under the federal program outlined in Section 201 of the 1972 Amendments to the Federal Water Pollution Control Act. This requires that a municipality first submit a facility plan. Six municipalities within the Upper Yellowstone River basin have or are in the process of submitting such a plan. Section 208 of the 1972 Amendments to the Federal Water Pollution Control Act provides for area-wide waste treatment management plans. Such a plan is currently being conducted by the Mid-Yellowstone Area Planning Organization. Several of the counties in the 208 planning area are in the Upper Yellowstone River Basin: Yellowstone, Carbon, Stillwater, and Sweet Grass. This plan will consider, in part, the effects to water quality from point sources such as municipal, agricultural, and industrial discharges, from non-point sources such as those associated with land use practices, and from increased recreational use due to the increase in coal development in the Middle Yellowstone River Basin. Under the new federal grant problem (Section 201), Step 1 is a facility plan. The facility plan for a number of communities within the basin will be done as a part of the 208 plan being conducted by the Mid-Yellowstone Area Planning Organization.

IV. BASIN PHYSICAL CHARACTERISTICS

GENERAL FEATURES

The Upper Yellowstone River basin (Plate I and Figure 1) is located in the south central part of Montana. It encompasses the eastern slopes of the Rocky Mountains of the western edge of the Great Plains. The basin has a varied topography ranging from flat valley bottoms in the northeastern section to extremely mountainous country in the southwest portion. Mountain ranges in the Upper Yellowstone River basin are: Gallatin, Bridger, Crazy, Absaroka, and Beartooth. Elevations in the basin range from 12,799 feet (Granite Peak in the Absaroka Mountains) to 3,300 feet (Yellowstone River Valley bottom near Laurel).

There are two designated wilderness areas in this basin, the Beartooth and Absaroka. The Upper Yellowstone River basin includes the following Montana counties in the approximate percentages listed:

Yellowstone	30%	Sweet Grass	95%
Carbon	80%	Park	99+%
Stillwater	95%	Gallatin	5%

This is a total land area of about 8845 square miles. The Upper Yellowstone River basin includes the Yellowstone River and all of its tributaries from the Yellowstone National Park boundary to but not including Pryor Creek. The major tributaries to the Yellowstone in this reach are: the Gardiner River, the Shields River, the Boulder River, the Stillwater River, and the Clarks Fork Yellowstone River.

In the Upper Yellowstone River basin, 16 municipal sewage wastewater discharges, 3 municipal water treatment plant discharges, 9 industrial wastewater discharges, 2 irrigation return discharges, and 20 confined feeding operations are not under a state or federal discharge permit.

The U. S. Geological Survey monitored 37 sites for flow within or adjacent to the Basin. All surface waters within the Upper Yellowstone River basin have been classified by the State of Montana. The Yellowstone River and its tributaries with the exception of those listed below are designated B-D_1:

West Fork of Rock Creek drainage to the Red Lodge water supply intake . . . . A-open-D_1

Clarks Fork Yellowstone River mainstem from Jack Creek to the Yellowstone River and the Yellowstone River drainage from the Laurel water supply intake to the Billings water supply intake . . . . B-D_2

Yellowstone River drainage below the Billings water supply intake. . . . . .B-D_3

An "A-open" classification designates that the quality of the water be maintained suitable for drinking; culinary and food processing purposes after simple disinfection and removal of naturally present impurities. A "B" classification designated that the quality of the water be maintained suitable for drinking; culinary and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection and any additional treatment necessary to remove naturally present impurities. The "D-1" classification further designates that the quality of the water be maintained suitable for bathing, swimming and recreation; and the growth and propagation of salmonoid fishes and associated aquatic live, waterfowl and furbearers. The "D-2" characteristics further designates that the quality of the water be maintained suitable for bathing, swimming and recreation, and the marginal growth and propagation of salmonoid fishes, and associated aquatic life, waterfowl and furbearers. The "D-3" classification further designates that the quality of the water be maintained suitable for bathing, swimming and recreation; and the growth and propagation of nonsalmonoid fishes and associated aquatic life, waterfowl and furbearers. The detailed criteria for the "A-open-D_1", "B-D_1", "B-D_2", and "B-D_3" classifications are given in Montana's Water Quality Criteria, Water Use Classifications and Policy Statements (Appendix B).

The Upper Yellowstone River basin with the exception of the Gardiner River drainage, the Upper Stillwater River drainage, a portion of the lower Clarks Fork Yellowstone River drainage, and the Yellowstone River in the vicinity of Laurel and Billings is classified as effluent limited waters. This classification indicates that the water quality is meeting or will meet applicable water quality standards after the application of effluent limitations required by the Federal Water Pollution Control Act Amendments of 1972. The exceptions referred to above are classified as water quality limited waters. This classification indicates that the water quality is not meeting and is not expected to meet applicable water quality standards even after application of the effluent limitation required by the 1972 Amendments to the Federal Water Pollution Control Administration. Table 1 is a list of the major streams in the Upper Yellowstone River basin. Also included in Table 1 is the Department of Natural Resources and Conservation's sub-basin designation, the drainage area, and the receiving waters (Ref. 1).

CLIMATE

The complex of mountains, valleys, and streams in the Upper Yellowstone River basin is very important to the climate.

Table I

Major Streams in the Upper Yellowstone Basin

Stream	DNR&C Sub-basin Designation	Drainage Area in Square Miles	Receiving Waters
Yellowstone River - Park Boundary to and including Bridger Creek	43B	2550	Yellowstone River
Shields River	43A	875	Yellowstone River
Boulder River	43BJ	520	Yellowstone River
Sweet Grass Creek	43BJ	340	Yellowstone River
Yellowstone River - Bridger Creek to the confluence of the Clark Fork of the Yellowstone	43QJ	690	Yellowstone River
Stillwater River	43C	1050	Yellowstone River
Clark Fork of the Yellowstone River	43D	1580	Yellowstone River
Yellowstone River from confluence of the Clark Fork of the Yellowstone to the confluence of Pryor Creek	43Q	1240	Yellowstone River

The climate of the basin is generally of a continental nature, but there are several modifications in the area where the plains meet the mountains. The Clarks Fork Yellowstone River valley near Belfry is the driest part of the basin and one of the driest places in Montana. The average annual precipitation is about six inches. This is probably due to the rain shadow effect of the Beartooth Mountains. The average annual precipitation for the basin ranges from about 35 to 6 inches. The majority of the precipitation in the lower valleys and agricultural areas occurs during the growing season - April to September. Precipitation in the mountainous areas is fairly steady throughout the year. Much of the precipitation during the winter months occurs as snowfall. Wide diurnal and seasonal variations of temperature are characteristic of the Upper Yellowstone River basin. The The frost free period is about 120 days. Although this is relatively short, crop growth is stimulated by the long hours of daylight and the greater intensity of sunshine incident to high altitudes (Ref. 3-9). Figure 2 shows the average monthly temperatures (Ref. 1) and precipitation for several reporting stations in the basin (Ref. 10).

LAND USE

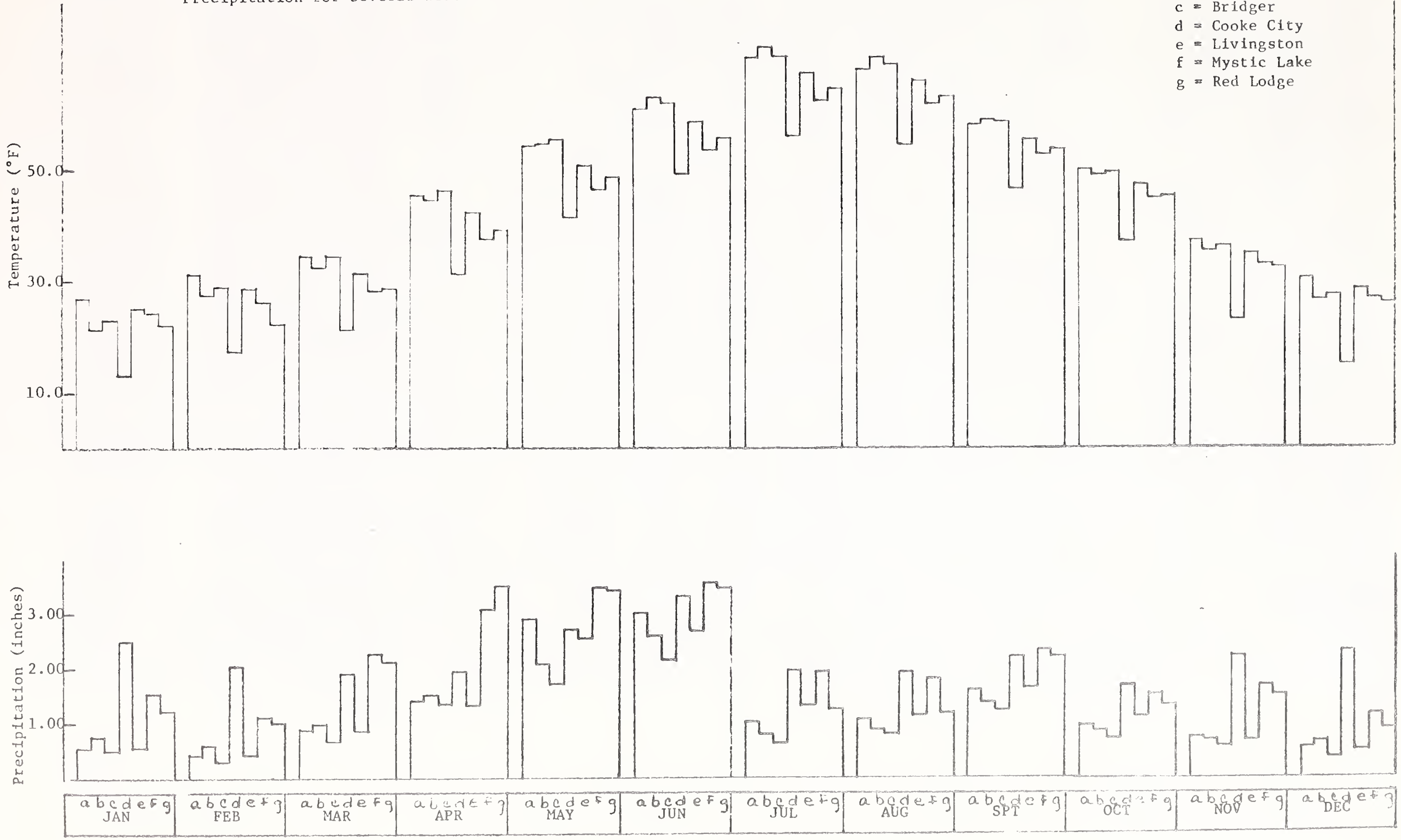
The Yellowstone River has its headwaters in Yellowstone National Park and flows into Montana near Gardiner. The Upper Yellowstone River basin consists of the Yellowstone River watershed from Gardiner to Huntley, comprising an area of 8,045 square miles or 5,148,984 acres. Cropland covers 2,965,500 acres with 2,678,700 acres in non-irrigated or dryland crops, including wheat, barley, oats, alfalfa and hay. About 286,800 acres of irrigated cropland produce primary crops of hay, barley, spring wheat, sugar beets, dry beans, and corn. Approximately 9,400 acres are covered by small water areas (ponds 2-40 acres in size) representing less than 1 percent of the area.

About 30 percent (1,524,000 acres) of the Upper Yellowstone River basin is made up of forest land. Ninety-nine percent of this total contains portions of the Gallatin and Custer National Forests. In 1969 approximately 28 million board feet of lumber were produced in this area. However, much of the public land is considered range land and contributes to the extensive livestock production in the basin.

Billings and Livingston are the major population and trade centers of the planning unit with 1970 populations of 61,581 and 6,883 respectively. Urban and build-up areas comprise an approximate area of 54,300 acres.

Extensive recreational opportunities exist in the Upper Yellowstone River basin on 2,029,440 acres of public lands.

Figure 2. Graph of Average Monthly Temperature and Precipitation for Several Weather Stations.



The main stem has national recreational importance because it offers about 95 miles of "blue ribbon" trout fishing from the Park County boundary to the Town of Big Timber. Access to lakes, streams, and rivers is facilitated by 1,280 acres of state owned or leased lands for public use. The Beartooth Mountains provide excellent opportunity for outdoor recreation. The Beartooth Primitive Area encompasses 230,000 acres in Custer and Gallatin National Forests. These mountains also offer two alpine skiing resorts which are just southwest of Red Lodge.

WATER USE

The largest portion of the water used in the Upper Yellowstone River basin is for irrigation. An estimate of water depleted for irrigation is 788,700 acre-feet per year. Most of the irrigation has been developed privately by individuals and small groups through construction of diversions and small dams. The Big Ditch Company was irrigating 23,484 acres of the planning unit by 1974. The project, begun in 1882, continues to expand as new land is developed along the system. Cove Irrigation Company, also constructed by private entities, was irrigating 6,330 acres in 1974. Sweet Grass Canal and Reservoir Company, started in 1906, was irrigating 2,695 acres in 1950 with an additional potential of irrigating 5,334 acres as land developed. The Park Branch Canal project was first operating in 1937 and in 1951 was irrigating 4,508 acres along the Yellowstone River with a potential 1,561 additional acres. There are no federal irrigation projects by the U. S. Bureau of Reclamation in the Upper Yellowstone River basin unit. The Montana Department of Natural Resources and Conservation operates Cooney Reservoir on Red Lodge Creek. The reservoir is fed by Red Lodge and Willow Creeks storing 27,515 acre-feet of water and providing 24,000 acre-feet of water for supplemental irrigation.

Municipal supplied water totals 7,884,100,000 gallons per year or 24,200 acre-feet. Ninety percent of this water is withdrawn from the Yellowstone River by four communities (Billings, Laurel, Livingston, and Gardiner). There are large quantities of water supplied from Billings (705,000,000 gallons per year) and Laurel (100,000,000 gallons per year) municipal systems for industrial water. Continental Oil Company buys 448,000,000 gallons from the town of Billings. The Montana Power Company, Corette steam electric generation plant acquires 14,600,000 gallons of water from Billings for boiler makeup. Great Western Sugar refinery purchases 68,400,000 gallons per year from Billings for the refining of sugar beets.

The Montana Power Company 10 megawatt plant at Mystic Lake on West Rosebud Creek is the only hydroelectric generating facility in the planning unit.

Rural domestic water use approaches 400 million gallons per year (1,230 acre-feet), nearly all of which is derived from groundwater sources. Livestock water use is estimated at 2,670,000 gallons per year (3,000 acre-feet per year) and is derived from both ground and surface water sources.

HYDROGEOLOGY

Groundwater is widely used in the Upper Yellowstone River basin, primarily for domestic and stock use and to a lesser extent for irrigation and public water supply. Groundwater is widely available in the basin, and constitutes a valuable basin resource. The availability, distribution, and quality of groundwater is directly related to the geological history of the area. The basin contains a wide variety of rocks of many different geological ages, which reflect the complex geological history of the basin. This history involves long periods of sedimentation, structual deformation, implacement of large igneous masses, erosion and glaciation. The geological history of the basin includes long periods of sedimentation punctuated by periods of uplift and volcanism. Faulting, folding, and uplift were dominant forces forming the mountain ranges in the basin. Glaciation occurred in the high mountains of the basin. The geological units of significance to the water resources of the basin are:

1. Igneous and metamorphic rocks of Pre-Cambrian age (over 600 million years old).

2. Sedimentary bedrock formations of Paleozoic age (230 to 600 million years old).

3. Mesozoic (65 to 230 million years old) age.

4. Igneous and sedimentary rocks of Tertiary (one to 70 million years old) age.

5. Alluvium and sedimentary rocks of Tertiary and Quaternary Age (less than one million years old).

Pre-Cambrian igneous and sedimentary rocks are present in the rugged Beartooth and Absarokee mountain ranges in the south-central portion of the basin. These rocks generally have had little groundwater development and generally have low porosity and permeabilities (ability to store and transmit water). Generally, they will yield little or no water to wells, but fractures and fault zones can yield good quality water in sufficient amounts for stock and domestic purposes.

Sedimentary rocks of Paleozoic and Mesozoic age are exposed in large portions of the eastern one-third of the basin, along the Yellowstone River upstream from Livingston, and along the perimeter of the Absarokee and Beartooth Mountains. There is a large variety of rock types present in the Paleozoic and Mesozoic deposits, including shale, quartzite, conglomerate, limestone, sandstone, siltstone, and dolomite. Generally, these rocks are present in mountainous terrain and have not been developed to determine their water yielding potential. Many sedimentary formations, such as the Madison Formation, Flathead Quartzite, and Eagle Sandstone are the source of numerous springs in the mountains and are potentially good water-bearing formations. It is expected that many water-bearing formations of Paleozoic and Mesozoic age would yield small to large quantities of fair to excellent quality groundwater to wells.

Underlying a significant portion of the northwestern part of the basin is the Livingston formation. It is both Cretaceous and Tertiary in age and consists of assorted volcanic material, including grit, sandstone, shale, and agglomerate. Generally, the water-yielding characteristics of this formation are poorly known; however, a number of wells in northern Park County are drilled into the Livingston formation, and numerous springs originate from this formation.

Large exposures of volcanic rocks, including andacite, dacite, and basalt are present in the upper portion of the Yellowstone River south of Livingston and in the mountains south of Big Timber. These rocks generally have low porosities and permeabilities, and generally will yield little or no water to wells. Fractures and fault zones encountered can yield good quality water in sufficient amounts for stock and domestic purposes. Groundwater in areas underlain by these volcanic rocks has undergone little development due to their poor water-yielding ability and the mountainous terrain associated with their exposures. These rocks, however, are the source of numerous springs.

The Fort Union Formation of the Tertiary age covers a significant portion of the basin in a broad belt extending from Red Lodge northwestward to the northern limit of the basin. The Fort Union Formation, wherever it has not been eroded, attains a thickness of over 2,000 feet. The Fort Union is composed of three members -- upper Tongue River Member, middle Lebo Member, and lower Tullock Member. Sandstone lenses and associated coal seams in the Tongue River and Tullock Members will commonly yield small amounts of water of fair quality to wells. The Lebo Member is mostly a shale and is essentially nonwater-bearing.

Alpine glaciation occurred in high mountain ranges in the south-central portion of the basin during the Pleistocene epoch (20,000 to one million years ago). Morainal deposits were left in high mountain valleys and along the Yellowstone River valley. These deposits consist of compacted mixtures of boulders, gravel, sand, silt and clay. Outwash deposits of sand and gravel commonly will yield small to moderate quantities of groundwater to wells, but most of the glacial deposits will yield little water to wells.

The most widely used, dependable, and productive aquifer in the basin is alluvial floodplain material of Recent and Pleistocene age present along all major streams and their tributaries. In general, wells will yield moderate to large amounts of water that is generally good to excellent in quality. These unconsolidated deposits consist of mixtures of boulders, sand, gravel, silt, and clay and are commonly 25 to 100 feet thick.

Pollution of groundwater has occurred in a number of areas in the Upper Yellowstone River basin. Petroleum products have polluted groundwater over significant areas in the vicinity of Livingston, Laurel, and Billings, and Billings Heights. Contamination of groundwater in these areas is caused by phenolic compounds, oil, and other petroleum products. Industrial stockpiling of chromate ores in the vicinity of Columbus has resulted in the pollution of a groundwater zone adjacent to the Yellowstone River in Columbus. Lagoon wastes from the Great Western Sugar Company in Billings have, in the past, polluted a localized groundwater zone in the vicinity of the lagoons with wastes that have seeped from the ponds. This groundwater pollution problem is periodic and is associated with the seasonal pond use of the sugar refinery. Recent pond sealing has significantly reduced this problem. In the upper portion of the Stillwater River drainage, there is pollution of surface water due to seepage of acid mine waters from underground workings and from areas disturbed by mining.

Septic tanks and subsurface disposal systems can create localized areas of groundwater pollution. Where there are large numbers of septic tanks and individual water supplies using wells, groundwater pollution can occur if these facilities are improperly designed and located. Such problems have tentatively been identified in the Livingston area and in the Billings Heights area, but have not been thoroughly investigated.

Another groundwater problem that has been identified in the basin is the saline seep problem. Saline seeps are created when precipitation infiltrates into salt-laden earth materials, thereby dissolving salt and subsequently redepositing the salt in areas of groundwater discharge. Saline seep areas have been identified north and particularly northwest of Billings. These seeps cover significant areas and indicate broad areas underlain by saline groundwaters.

POPULATION AND ECONOMICS

For this profile, 1970 census data from county census divisions has been summarized to approximate the actual basin figures. The census gives a county-by-county accounting of people and jobs as of 1970. This data was then applied to historic data and county projections to yield Table 2A. Because of the importance of coal development to the basin's economic future, a special set of projections have been included which consider coal related population and employment.

With the exception of Billings, agriculture is the area's predominant economic activity. A subtantial amount of the basin is irrigated with hay, pasture, corn for silage and sugar beets being the major crops. The major use of unirrigated lands is range with extensive dry grain production in some areas. Marketing receipts from livestock are more than twice those of crops.

Billings, with well over half of the basin's population, is the wholesale center for the entire region and also handles a large portion of the retail trade. With a population of 61,581, Billings is the largest city in Montana. Although Table 2A shows that the population of the basin has been increasing for the last forty years, the figures are somewhat misleading. From 1960 to 1970, the population decreased in every county in the Upper Yellowstone basin except Yellowstone County, which is the location of Billings. There has been a transfer of the population from the rural areas to the metropolitan area of Billings.

TABLE 2A

POPULATION AND EMPLOYMENT, HISTORICAL AND PROJECTED, 1930 - 1985

	1930	1940	1950	1960	1970	1980	1985
Population	62,791	71,923	84,508	105,764	109,412	124,803[a] 129,408[b]	131,030[a] 135,936[b]
Employment	24,702	23,932	32,089	39,128	41,634	47,161[a] 48,818[b]	49,591[a] 51,355[b]

[a]Population projection is strictly a historical projection. No inclusion of coal impact.

[b]Population projection includes the expected coal impact. From: "Coal Mining and Employment," Montana State Employment Service, Billings Office, April 1974. This assumes that 47% of the impact will occur in Billings.

Table 2A summarizes both historical population and employment from 1930 to 1970. Two projections to 1980 and 1985 have been made. The first is a historical projection that does not include coal development.

The second has added primary and derivative jobs and population based on a State Employment Service study of coal impacts. It is important to note that if energy firm's plans for mining and processing coal in the Middle Yellowstone area materialize, the resultant impact upon the Upper Yellowstone basin could be much greater than shown. An additional influx of population also could occur if the plans for underground mining in Carbon County materialize. Tourists have a significant role in the economy of the basin. With a ski resort at Red Lodge and the entrance of the Yellowstone National Park in Park County, there is a constant flow of tourist dollars into the Upper Yellowstone basin.

Table 2B shows that manufacturing is important in the basin economy. Food and kindred products, printing and publishing, fabricated metal industries and the production of many other durable and nondurable goods are all part of the basin's economy, although the vast majority of the industry takes place in Billings. Table 2B also points out the importance of education in the basin's economy. With Eastern Montana College and Rocky Mountain College both in the basin, some 8.6 percent of the basin's total working force are involved in education. Table 2C lists the major communities in the basin.

SOILS

Soils of the Upper Yellowstone River basin are as varied as the physiographic features, and the interesting and complicated geologic history has greatly influenced the soils of the area. Dominating physiographic features in the basin are broad stream valleys bordered by high steep mountain ranges.

As a result of isolated mountain glaciation, some areas are covered by glacial outwash deposits. Extensive drainage throughout the area over periods of time has resulted in erosion of the mountainous terrain and the subsequent filling of the stream valleys and drainage basins with alluvial material. The soils are made up of alternations of alluvium and other geologic parent materials of the mountains and of the eastern basin plains due to conditions of climate, topography and living organisms over time.

The higher mountain areas are generally a rockland with little soil development. A fair portion of the mountainous area consists of rock outcrops, rock slides and rock-walled canyons. Where a soil mantle of varied depth has developed over rock, timber is the dominating vegetation.

On the more gentle slopes, alluvial fans and stream terraces have developed soils with a cobbly loam surface and a clayey subsoil. On sloping bedrock benches, soils generally have a granular surface which overlies a prismatic clay subsoil which is very hard when dry. A lime layer may not be present, but may contain up to 30 percent lime, if present. Loams and sandy loams have developed over sandstone which can be encountered at depths of 20 feet. These soils tend to be dry and management practices should be directed toward prevention of wind erosion.

TABLE 2B

EMPLOYMENT BY GROSS SECTORS, 1970

Sector	Number	Percent of Total
Agriculture	3,397	8.2
Forestry and Fisheries	132	0.3
Mining	304	0.7
Construction	2,653	6.4
Manufacturing	3,226	7.7
Eating and Drinking Places	2,027	4.9
Education	3,592	8.6
Health Services	2,264	5.4
Motor Vehicle Retail and Services	1,493	3.6
Legal, engineering, miscellaneous professional services	944	2.3
Other Retail Trade	2,783	6.7
Public Administration	1,869	4,5
Other	16,950	40.7
TOTAL	41,634	100.0%

On fine textured sedimentary rocks and on convex slopes at crests of hills and ridges, soils with clay loam surface and platy clay loam subsoil have developed. On convex slopes on ridge crests and valley sides underlain by soft siltstone and sandstone, soils with silt loam subsoil have developed. All these soils present a severe erosion hazard.

On nearby level to gently sloping alluvial fans and terraces consisting of loose sands and gravels, soils have developed with a granular loam surface and a prismatic clay loam subsoil. On medium textured alluvium, soils are found with silt loam surfaces that rest on stratified silt loam, clay loam and sandy loam subsoils. These soils present a water erosion hazard.

Many soils in the larger river valleys are irrigated. Evidence of increased soil salinity can be noticed in some areas due to improper drainage. Saline seep has also been noticed in the northern part of the drainage basin.

TABLE 2C

COMMUNITIES OF 100 OR MORE PERSONS

Community	County	1970 Population
Billings	Yellowstone	61,581
Laurel	Yellowstone	4,454
Absarokee	Stillwater	600
Columbus	Stillwater	1,173
Park City	Stillwater	430
Reed Point	Stillwater	133
Belfry	Carbon	250
Bridger	Carbon	717
Edgar	Carbon	210
Fromberg	Carbon	364
Joliet	Carbon	412
Red Lodge	Carbon	1,844
Roberts	Carbon	200
Silesia	Carbon	100
Big Timber	Sweet Grass	1,592
Clyde Park	Park	244
Gardiner	Park	600
Livingston	Park	6,883
Wilsall	Park	200

V. MONTANA WATER POLLUTION CONTROL PROGRAM

INTRODUCTION

Water quality management planning is part of a broad, comprehensive water pollution control program administered by the Water Quality Bureau of the Environmental Sciences Division of the Montana Department of Health and Environmental Sciences. Details of this program are described in annual reports of the bureau. Important elements of the state program are:

1. State and federal waste discharge permit programs.

2. Water quality standards.

3. Statewide monitoring and surveillance.

4. Facilities construction grants, plan review, operation and maintenance inspections, training and licensing of operators.

5. Public participation.

6. Enforcement.

STATE AND FEDERAL WASTE DISCHARGE PERMIT PROGRAMS

The present state program of issuing waste discharge permits is operated under the authority given by the Montana water pollution control law and the Montana Pollutant Discharge Elimination System (MPDES). At the present time, the U. S. Environmental Protection Agency (EPA) is also issuing waste discharge permits in the state of Montana to federal facilities and to discharges, from other than incorporated communities, on Indian reservations. The permits are being issued pursuant to the National Pollutant Discharge Elimination System (NPDES) created by the Federal Water Pollution Control Act Amendments of 1972 (FWPCAA of 1972). To eliminate the duplication of effort which formerly existed, the state of Montana applied for and received authority from EPA to issue NPDES permits in Montana. Section 402 of the FWPCAA of 1972 provides that states with adequate water pollution control programs may apply for and receive authority from EPA to issue discharge permits under the NPDES in their own states. Montana made the necessary revisions to the state water pollution control laws during the 1973 legislative session to provide statutory authority for administration of the NPDES program in Montana. The Montana Department of Health and Environmental Sciences was given the authority to administer the waste discharge permit program on June 10, 1974. Waste discharge permits issued under the NPDES prior to the MPDES permit program will serve as MPDES permit until their date of expiration. All MPDES permits issued meet the minimum requirements of the EPA for NPDES permits.

The Federal Water Pollution Control Act Amendments of 1972 established the following time schedule for upgrading waste treatment facilities:

MUNICIPALITIES

1. Secondary treatment, and any more stringent limitation necessary to meet water quality standards, by July 1, 1977.
2. Best practical control technology by July 1, 1983.
3. No discharge of pollutants by 1985 (goal).

INDUSTRIES

1. Best practicable control technology by July 1, 1977.
2. Best available control technology by July 1, 1983.
3. No discharge of pollutants by 1985 (goal).

NATIONAL SECONDARY TREATMENT REQUIREMENTS (FWPCAA OF 1972)

Minimum five-day biochemical oxygen demand (BOD_5) reduction to 85 percent.

Minimum suspended solids reduction of 85 percent.

Maximum effluent BOD_5 of 30 mg/l on monthly average and 45 mg/l on weekly average.

Maximum effluent suspended solids of 30 mg/l on monthly average and 45 mg/l on weekly average.

Maximum effluent fecal coliform of 200 organisms/100 ml on monthly average and 400 organisms/100 ml on weekly average.

Limits of pH on effluents maintained between 6 and 9.

Self-monitoring of these parameters is required. The frequency of monitoring is based on the population served and the complexity of the treatment facility and is stated in the NPDES or MPDES permit. In addition, some municipal dischargers are limited for and required to monitor effluent oil and grease.

WATER TREATMENT PLANT TREATMENT REQUIREMENTS

There are no parameters specified by the FWPCAA of 1972 to be monitored for water treatment plant discharges. The following requirements are being placed on NPDES permits issued in Montana:

1. No change in operating procedures will be allowed that would result in a less desirable discharge.

2. As soon as practicable but no later than July 1, 1977:

Total suspended solids (TSS)	<45 mg/l weekly average <30 mg/l monthly average
Total dissolved aluminum	<1.0 mg/l monthly average <1.5 mg/l grab sample
pH	Maintained between 6.0 and 9.0

INDUSTRIAL BEST PRACTICABLE CONTROL TECHNOLOGY REQUIREMENTS (FWPCAA OF 1972)

Industrial waste dischargers will be required to provide the best practicable control technology currently available in treatment of their waste discharges. The parameters will be limited and monitored, and the frequency of monitoring will vary with the different types of industries. The specific parameters to be limited and monitored and the frequency of monitoring are stated in the NPDES or MPDES permit.

AGRICULTURAL TREATMENT REQUIREMENTS (FWPCAA OF 1972)

Any animal confinement facility which on any 30 days during the previous 12 months contained 1,000 or more animal units or any animal confinement facility, without regard to size, which discharges to state waters must apply for a waste discharge permit. In addition, any facility in close juxtaposition to a stream or with the potential for affecting a nearby stream could be required in the future to apply for a waste discharge permit regardless of the number of animal units. The following is a list of the number of animal units for those types of animal confinement facilities in or expected to be in operation in Montana:

Slaughter and Feeder Cattle	1.0 animal units/animal
Mature Dairy Cattle	1.4 animal units/animal
Swine over 55 pounds	0.4 animal units/animal
Sheep	0.1 animal units/animal
Fish (where discharge occurs on at least 30 days/year)	0.05 animal units/pound

As noted, pending regulations currently before the Environmental Protection Agency could expand these requirements to include those facilities where (1) measurable wastes are discharged directly into any navigable waters that transverse the operation, or where (2) measurable wastes are discharged into navigable waters by the means of a man-made conveyance specifically constructed for wastewater disposal, or where (3) measurable wastes are otherwise a significant source of pollution. Comments to these proposed regulations are generally concerned with a clarification of terminology, e.g., "measurable waste."

The waste discharge permits issued for animal confinement facilities will generally prohibit any discharge of pollutants unless rainfall in excess of the 10-year/24-hour rainfall or equivalent moisture has been received.

Irrigation return flows will be subject to MPDES permit if there is a point source discharge through a man-made or man-maintained drainage system from 3,000 or more irrigated acres. The parameters to be monitored and the frequency of monitoring will be stated on the discharge permit. However, some revisions of these requirements will probably be made in the near future.

WATER QUALITY STANDARDS

Water pollution control started in Montana in 1907 with passage of legislation designed to protect domestic water supplies. A more comprehensive law was passed in 1955 that dealt with control and protection of water for recreation, agriculture, and industry. The 1955 law also established a water pollution control council and charged it with the tasks of classifying all streams in the state according to their most beneficial uses and establishing water quality criteria for the streams. The 1955 law also involved upgrading the treatment of wastes going into the streams. Montana thus became one of the first states to have enforceable stream classifications.

In 1965, the U. S. Congress passed the Federal Water Quality Act which required that all states classify and establish water quality criteria for their interstate streams by July 1, 1967. Montana revised its standards for both interstate and intrastate waters and required a higher degree of stream quality than before. Secondary treatment or the equivalent was required of municipal and industrial discharges. In October, 1972, the Federal Water Pollution Control Act Amendments were passed expanding the authority of the Environmental Protection Agency. Uniform water quality standards and enforcement procedures throughout the United States became the objective. Montana revised its water quality standards and adopted these revised standards on July 13, 1973. The new standards became effective in November, 1973.

Montana water quality standards serve as a functional tool in protecting water quality; however, a number of laws, statutes, and regulations complement the water quality standards and significantly assist in protecting water quality.

STATEWIDE MONITORING AND SURVEILLANCE PROGRAM

Prior to 1972, Montana had done little water quality monitoring due to inadequate funding. With increased appropriations provided by the 1971 legislature and the federal government, the state greatly increased its effort. Personnel were added to the staff, and laboratory capabilities were expanded. The present state monitoring program includes compliance monitoring of point sources of wastes including monitoring of municipal and industrial wastes, long-term baseline monitoring of streams, and a statewide program for determining the general quality of all significant surface waters.

The statewide inventory of water quality will identify areas with water quality problems and will provide basic data for water quality management and planning programs. Included in the monitoring is a statewide assessment of the trophic (pollution level) status of Montana's lakes, reservoirs, and ponds. This program is coordinated with the EPA National Eutrophication Survey.

FACILITIES CONSTRUCTION, OPERATION, AND MAINTENANCE

A minimum requirement of primary treatment for all domestic sewage was first adopted by the Montana Board of Health in 1952. All of Montana's communities have met this requirement, and many of the communities are upgrading their facilities to secondary treatment or are in the process of constructing or planning secondary treatment systems. Since 1956, there has been a federal grant program to assist municipalities in the construction of sewage treatment facilities, including outfall and interceptor sewers. In 1971, the Montana state legislature appropriated $4,000,000 to aid municipalities in construction of these same facilities. The 1973 legislature appropriated $1,600,000 to reimburse municipalities that had proceeded with construction since July 1, 1966, without waiting for state grants. With passage of the Federal Water Pollution Control Act Amendments of 1972, 75 percent of eligible project costs are federally financed. Due to a shortage of federal grant funds, a priority system for allocation must be used. The state, under EPA guidance, establishes priorities for proposed waste treatment projects.

An important part of municipal sewage treatment is proper operation and maintenance of facilities after construction is completed. In an effort to improve operation and maintenance, the state has conducted an operators' school each year. During recent years, this school has had about 100 operators attending. In 1971, a grant was obtained from the federal government for employing two training instructors to establish training programs throughout the state. This activity is in addition to the annual school.

An operators certification program was established in 1968 following enactment of a law requiring certification of those responsible for the operation of sewage treatment or industrial waste treatment systems.

PUBLIC PARTICIPATION

Public participation in the water pollution control is an increasingly important aspect of the state program. Public hearings are held concerning proposed regulations, water quality management plans, and waste discharge permit applications. The state also has an environmental impact statement requirement. These statements are presented to the public for comment, and hearings are conducted on highly controversial issues.

The public also is kept informed by means of a water pollution control advisory council which has been established by law to assist the Water Quality Bureau in preparation of rules and regulations and dissemination of information to interested groups. Similarly, public meetings are attended on request, and a quarterly newsletter is published by the Water Quality Bureau.

ENFORCEMENT

Montana's laws on water pollution basically state (1) it is unlawful to cause pollution or place materials in a location where they are likely to cause pollution of state waters, and (2) discharge of waste material into state waters without a permit from the Department of Health and Environmental Sciences. Two administrative rules have been adopted by the Board of Health and Environmental Sciences which are the chief elements in Montana's water pollution control program. Montana's water quality standards serve as the primary means for defining pollution, and the Montana Pollutant Discharge Elimination System rule provides the mechanism for authorizing and controlling point source discharges to state waters. Violators of the law, a rule, permit, or order could be subject to injunction, civil penalties up to $10,000 for each day of violation, or criminal penalties with fines not to exceed $25,000 per day of violation and/or imprisonment for not more than one year for an initial conviction and not more than $50,000 per day of violation and/or imprisonment for not more than two years for subsequent violations. Significant steps were taken in 1974 to establish a workable enforcement program, including increasing the legal staff and additional allocation of technical staff.

VI. WATER POLLUTION SOURCES

GENERAL

Water pollution in the Upper Yellowstone basin is caused by several factors including municipal and industrial discharges, acid mine drainage from active and inactive mines, runoff from mismanaged and erodable soils and agricultural wastewaters. There are 13 municipal sewage treatment facilities with active discharges and there are nine industrial installations that have discharges to the Yellowstone River. Characteristics of significant municipal and industrial discharges are summarized in Tables 3, 4, and 5. Compliance information and permit numbers are given in Appendix D.

MUNICIPAL DISCHARGES

Several communities in the study basin discharge treated sanitary wastewater and water treatment plant backwash water to adjacent streams. Billings, Laurel, and Livingston provide primary wastewater treatment at the present time. Billings is currently undergoing construction for a complete mix, activated sludge, secondary treatment plant that should be operational within the next year. Most other communities in this section of the river have wastes that are treated by sewage stabilization ponds. The assessments of community needs are based on the fact that the Upper Yellowstone basin consists of effluent limited and water quality limited segments. The following assumptions are made in regards to meeting of secondary treatment requirements.

1. Meeting secondary treatment requirements is considered satisfactory for effluent limited drainages.

2. For lagoon systems, it is assumed that only those having a minimum of three cells designed on both an organic and hydraulic basis in series with disinfection of the effluent are considered capable of meeting secondary treatment requirements. Properly sized aerated lagoons, followed by polishing ponds and disinfection, are also considered to be capable of meeting secondary treatment requirements.

3. Hydraulic loading was evaluated on the basis of 100 gallons per person per day. The lagoon system should be capable of holding 180 days of flow without discharge from the lagoon.

4. A lagoon designed on the basis of one surface acre per 100 population will approximately meet the above design criteria. It is assumed at the present time, however, that single cell lagoons in the Upper Yellowstone basin are not sufficient to achieve the required degree of treatment. It is also assumed that a two-cell lagoon will seldom meet the required secondary treatment. Under these assumptions prospective needs are based on a three-cell lagoon with adequate chlorination.

BILLINGS WASTEWATER TREATMENT PLANT

Existing primary treatment facilities for the City of Billings consist of grit removal and screening with four 125 foot diameter primary clarifiers that are followed by sludge digestion, vacuum filtering, and chlorination of sewage effluent. The final discharge, that averages 12 million gallons per day at present time, is to the Yellowstone River. Improvements that are presently underway to the existing plant consist of complete mix aeration facilities, additional vacuum filtering with heat treatment of sludge instead of the present digestion facilities. The new plant will also contain four secondary clarifiers and disinfection facilities. The plant is designed for treatment of wastes from approximately 120,000 people plus an unknown amount of industrial effluent. The hydraulic design of this treatment plant is about 30 million gallons per day. The waste solids from the vacuum filtering process will be landfilled in the Billings landfill facility.

BILLINGS WATER TREATMENT PLANT

The water treatment facility at Billings utilizes water from the Yellowstone River. The treatment consists of flow measurement systems, rapid mix and coagulation basins, covered sedimentation basins, six mixed media filters, clearwell, high service pumps and chemical feeding systems necessary for treatment. The six rapid sand filters from the older facility have been discontinued and will not be used. Contracts have been let by the City of Billings for an addition to the water treatment facility that will add four double mixed media filters to the existing six filters which will give the water plant a total capacity of approximately 75 million gallons per day. The silt presently collected in the primary settling basin is removed by a floating dredge and is landfilled in the vicinity of the water treatment plant. The discharge from the filter backwashing and the coagulation and rapid mix basins is directly to the Yellowstone River. The two discharges are combined in the water plant, but the pipeline divides and there are two points of discharge in the Yellowstone River. No treatment is given to these discharges. With the completion of the new water treatment plant and related facilities, all discharges to the Yellowstone River will be discontinued.

LAUREL WASTEWATER TREATMENT PLANT

The wastewater treatment for Laurel presently consists of gravity mains, a two pump ejector type lift station in the collection system, and a primary wastewater treatment plant that consists of bar screen, comminuter, primary clarifer, chlorine feed and contact basins, final effluent lift pump, Parshall flume measuring device, two-stage heated digestion, and sludge drying beds. Sludge from the drying beds is transferred to a landfill for disposal.

The average daily discharge of the Laurel wastewater treatment plant, which approaches 1.2 million gallons per day, increases significantly during the summer and early fall months because of infiltration into the collection system. The needs for the City of Laurel at the present time are reduction of infiltration into the collection systems and the construction of a secondary treatment facility that will produce effluent in accordance with secondary treatment standards. The city is presently the recipient of a facilities grant and a consulting engineering firm is evaluating the collection system at the present time. During times of normal operation the discharge from this plant will flow by gravity to the Yellowstone River. However, when the Yellowstone River raises due to runoff and the infiltration in the collection system increases it is necessary to pump the effluent from the treatment facility. The new treatment plant which will cost approximately $1 million will have to be completed in order for the City of Laurel to meet secondary treatment requirements.

LAUREL WATER TREATMENT PLANT

The water supply for Laurel is obtained from the Yellowstone River. Treatment facilities include raw water pumps, six series mud basins, settling basins, two rapid sand filters, equipment for alum, sodium fluoride, and chlorine. Discharges from this treatment plant include pump lubrication cooling water, filter backwash water, and wastes from the settling basins and mud basins.

COLUMBUS

The sewage disposal system for the City of Columbus consists of gravity mains discharging into a two-cell lagoon that has a total surface of approximately 16 acres with the acreage spread evenly between the two cells. The discharge from this lagoon system, when it does occur, is to a drainage ditch that empties into the Yellowstone River. The lagoon system can be operated in a series or parallel operation. The present population served by the facility at Columbus is about 1281 people and the system has been discharging only on a seasonal basis in the past years. The lagoon appears to be satisfactorily designed on both a hydraulic and biological loading. The City is planning on possibly constructing a third cell for further treatment of any effluent from the lagoon system. The effluent from the third cell can then be utilized for irrigation. The town has land available for the proposed future additions so it is estimated that the total cost of the improvements would be approximately $15,000. It appears that the town will continue to have a non-discharging facility and will be in compliance with secondary treatment requirements.

BIG TIMBER

The sewage disposal for the City of Big Timber consists of gravity mains that discharge into a single cell lagoon with a total surface area of approximately 18 acres. The present population of Big Timber is estimated to be 1660. In view of this fact, it would appear that the present treatment system is adequately sized for the number of people it serves, but there appears to be a small infiltration problem in the collection system. It does not appear to hinder the operation of the lagoon, monitoring results from the effluent of this lagoon have indicated a satisfactory degree of treatment during the summer months. Discharges, however, during the winter months will not necessarily meet the required treatment. It is estimated that a second cell of approximately two acres will be needed to hold the winter flow. This addition to the sewage treatment system is expected to cost $40,000. Big Timber has recently received a 201 grant; they are now in the facility planning stage.

LIVINGSTON WASTEWATER TREATMENT PLANT

The sewage collection and treatment system for the City of Livingston consists of gravity mains, one ejector type lift station and primary mechanical sewage treatment plant that consists of grit settling chamber, mechanical bar screen, parshall flume measuring system, primary clarifier, primary digester, sludge storage digester, sludge drying beds and chlorination facilities. Sludge from the drying beds is transferred to a landfill for disposal.

The discharge from this treatment plant, which is approximately 2.6 million gallons per day, is directly to the Yellowstone River. Influent flows to this treatment plant at times exceed the hydraulic capacity of the system and a partial bypass is required to prevent flooding and overflowing of the primary basin. The city is presently the recipient of a first step facilities grant and a study has been made on the collection system and future treatment requirements necessary to enable the city to meet secondary treatment requirements. The needs for this plant in future sewage treatment are a reduction of infiltration in the collection system and a secondary treatment facility to meet required treatment standards. The probable cost of this modification is about $1.5 million.

LIVINGSTON WATER TREATMENT PLANT

The water treatment plant currently serving the needs of Livingston is utilized as a standby source of water. The main source of water for the City of Livingston is provided by wells. When the water plant is in operation, the discharge from the plant to the Yellowstone River consists of filter backwash water. There is no treatment facility provided for this water.

GARDINER

The sewage disposal system for the community of Gardiner consists of gravity mains, two two-pump lift stations in the distribution system and one two-pump main lift station that pumps the sewage across the Yellowstone River into an outfall line that empties into a two-cell aerated treatment lagoon. This aerated treatment system first began operation in 1972 and before that time the community was discharging inadequately treated sewage directly to the Yellowstone River. The two-cell lagoon is operated in a series pattern. The first cell has a surface area of 2.4 acres and is approximately 15 feet deep. The second cell consists of 1.7 surface acres and has an operating depth of approximately 10 feet. The main aerated facility is the larger cell. At the present time, there is no discharge from this facility with the effluent evidently being infiltrated into the porous and gravelly material on which the lagoon was built. When this system was first put into operation there was a discharge, but it appears that the water-tight membrane that has been installed on the bottom of the lagoon has ruptured. The lagoon system when discharging has chlorination facilities. The lagoon system treats the wastes of approximately 650 people on a year-around basis. The summer influx of tourists, however, greatly adds to the amount of sewage treated in this system.

GARDINER WATER TREATMENT FACILITIES

The community of Gardiner has two water supply systems, one of which produces a discharge to the Yellowstone River. The main source of supply for Gardiner is springs located near the edge of the community. During the summer months when the supply exceeds that produced by the springs a small fully automatic water treatment plant provides supplemental water. The discharge from this water treatment plant consists of filter backwash. There are no treatment facilities provided for the backwash discharge.

FROMBERG

The sewage disposal system for the Town of Fromberg consists of gravity mains, a single-pot, dual compressor pneumatic ejector pump station and a single-cell sewage treatment lagoon. The sewage treatment system for Fromberg is not adequate and will not produce an effluent that will meet secondary treatment standards. The Town has been placed on the priority list for funds for updating of the treatment system and as soon as funding is awarded, the system will be updated. The present cell has a surface area of 2.5 acres and discharges continuously with the exception of about 2 months in the late fall and early winter. To update the present system, which discharges less than 20,000 gallons per day, would result in a construction cost of approximately $15,000.

BRIDGER

The sewage disposal system for the Town of Bridger consists of gravity mains discharging into a single-cell lagoon with a surface area of approximately 9 acres. The population presently served by this lagoon is 824 which would indicate that the lagoon is sized according to population requirements The lagoon, however, discharges approximately 10 months of the year which would indicate that there is an infiltration problem within the collection system. Monitoring results of this lagoon indicate a satisfactory reduction of BOD_5 during the winter months. Some modifications will have to be made to this system in order to achieve secondary treatment standards that will be in compliance with requirements. It is estimated that an expenditure of approximately $50,000 would be required to update this system that has a discharge of approximately 45,000 gallons per day. No large increase in population is expected for the Town of Bridger in the next 10 to 20 years.

BEARCREEK

The small town of Bearcreek which has a population of 61, has a very short sewage collection line that discharges into a settling tank with a discharge directly to Bear Creek. It appears that there are approximately 7 or 8 residences on this sewer and no tests or measurements have been made of the outfall from the existing settling tank. The Town has been placed on the priority list to receive grant money to construct a sewage treatment facility, but at the present time there is no action on the proposed system. The town was formerly very active when the coal mining was at its peak, but since the coal mining has been stopped, the only inhabitants of the town appear to be retired people with modest income. The biggest obstacle to overcome in regards to construction of a sewage collection and treatment system will be the financing of such a facility.

JOLIET

The sewage disposal system for Joliet consists of gravity mains discharging into a modified aerated Imhoff tank. The old Imhoff tank has been equipped with an aeration system, a mechanical skimming device, and chlorination facilities. The discharge from this system is reported at approximately 350,000 gallons per day and the effluent being produced by this facility is meeting primary treatment standards. The community has an infiltration problem that needs to be corrected in order to keep from overloading the system hydraulically. Assuming a water usage of 150 gallons per capita per day, the flow through this system should not exceed 100,000 gallons per day. The Town of Joliet is expected to grow somewhat over the next 20 years so additional work will be necessary in order to put this system in compliance with requirements.

It is estimated that an expenditure of $20,000 should be sufficient to finance future modifications of this system.

ROBERTS

The sewage disposal system and treatment facility for the community of Roberts consists of gravity mains and a single-cell sewage treatment lagoon with a surface area of 3.4 acres. The estimated population serviced by this facility is 300 people. The discharge from the lagoon, which is approximately 200,000 gallons per day, is directly into Rock Creek. The treatment lagoon appears to be designed according to acceptable standards, but the high rate of infiltration in the collection system is hydraulically overloading the treatment facility. The needs of this community to update the system to put it in conformance with acceptable standards are a reduction of infiltration and a possible addition to the lagoon system. The estimated cost to complete the work is $300,000. Due to the high rate of infiltration, the lagoon system appears to be producing an acceptable effluent at this time. Discharges from this system occur on a seasonal basis and fluctuate greatly because of the infiltration problems. The community of Roberts is currently the recipient of a facilities grant and preliminary engineering work is being undertaken relative to the modification and improvement of this system.

BELFRY

The sewage disposal system for Belfry consists of gravity mains and one two-pump package lift station with a force-main that discharges to a two-cell treatment lagoon, with effective surface areas of 3.5 acres and 1.0 acres, respectively. The sewage collection and treatment system serves a population estimated at 250 and no major expansion of population is predicted for this community. The lagoon has operated since 1969 and there has been no overflow from this system nor is any overflow expected. The system meets secondary treatment standards because of the non-overflowing operation.

RED LODGE

The sewage collection and treatment system for the City of Red Lodge includes gravity mains that discharge into a six-pond sewage treatment system. The first three ponds of this system are from the older treatment facility and have a surface area of approximately one acre. The final three ponds, which were put into operation in 1971, have a surface area of approximately 20 acres. The current population being served by this treatment system is approximately 2,200 people. The discharge from this facility ranges from a low of 800,000 gallons per day to a maximum that would exceed 5,000,000 gallons per day. The city is currently the recipient of a facilities grant and an engineering firm is retained to make an accurate determination of the infiltration problems in the collection system. The high groundwater situation in the City of Red Lodge adds to the infiltration problems of this collection system. The discharge is currently meeting the stipulated effluent conditions, but the 85% reduction factor is not being met. The discharge from the final cell of this lagoon system enters a drainage ditch and flows for approximately two miles before it reaches Rock Creek into which it finally discharges. The estimated cost for the improvement and modification of this system is $290,000.

ABSAROKEE

The sewage collection and treatment system for the community of Absarokee consists of gravity collection system with a gravity discharge to a four-cell lagoon treatment system with a total surface area of approximately 1.5 acres. The final effluent from this lagoon system is discharged directly into a drainage ditch that empties into the Rosebud River. The collection system and main outfall line are currently hydraulically overloaded due to the high rate of infiltration into the collection system. The community is the recipient of a facilities grant that will study the infiltration problem and propose modifications and/or additions to the system to reduce infiltration. The treatment lagoon system is also hydraulically overloaded and the study will address the treatment system problems also. The system serves approximately 600 people and the discharge averages 750,000 gallons per day with a maximum discharge exceeding one million gallons per day. The estimated cost of the modifications and improvements to this system is $266,000.

EDGAR

The community of Edgar is served by a two-cell sewage treatment lagoon with a total surface area of 2.6 acres. The collection system discharges by gravity to the treatment facility and there is no discharge to the Clark Fork. There has been no MPDES permit issued because of the no-discharge status and it appears that no discharge will occur from this facility. No large population expansion is projected for Edgar, so it appears that the treatment facility is sufficient for some time.

PARK CITY

The community of Park City is served by a two-cell sewage treatment lagoon with a total surface area of 2.6 acres. The collection system includes a two-pump lift station which pumps into the treatment facility. An MPDES permit has been issued for this system, but no discharge has occurred. There is a possibility that future population expansion could cause the facility to become undersized, but adjacent land is available for expansion if necessary.

YELLOWSTONE BOYS RANCH

The Yellowstone Boys Ranch which is home for about 90 boys plus administrative and operating personnel is served by a two-cell sewage lagoon with total surface area of 1.6 acres. An MPDES permit has been issued for this facility although there has never been a discharge to surface waters. Additional adjacent land is available for expansion of the lagoon if a population increase could create an overloaded and underdesigned system. This facility will always meet existing discharge requirements because it will always be in a nondischarge category.

INDUSTRIAL DISHCARGES

There are nine known industrial dischargers in this portion of the Yellowstone basin. Six of these discharges are located in the Billings area, two are located in Laurel and one in Livingston. All of these industries are covered by MPDES permits; at the present time the majority of the discharges appear to be meeting permit requirements. In addition, one industry discharges into Silvertip Creek which eventually enters the Clarks Fork of the Yellowstone River; this discharge is derived from the Elk Basin Oil Field in the northern part of Wyoming.

EXXON COMPANY USA

One of the three refineries in the Billings-Laurel area, the Exxon Company USA refinery, has two discharge points. The cooling water discharge averages about 30,000,000 gallons per day and the only treatment that this discharge receives is oil skimming. The process water goes through the following mechanical and biological treatment systems: oil skimming through an API separator, settling basins, aeration facilities for biological treatment and final settling ponds before discharge to the Yellowstone River. The aeration basins are used for the removal of phenolic material and a reduction in the biochemical-oxygen demand. The remainder of the systems rely on mechanical means for skimming and removing floating oils and debris. The discharge from the process water averages approximately 4 million gallons per day with about half of this water being recirculated for reuse.

CONTINENTAL OIL COMPANY

The second refinery located in Billings has one discharge point for the discharge of their process water. The cooling water is recirculated and cooled through the use of cooling towers. The biological portion of the system consists of biological aerated ponds that remove the majority of the phenolic material. The discharge from the bio-ponds enters a larger aerated lagoon system that is equipped with oil skimming facilities and underwater aerators. This in turn proceeds to a second pond that utilizes surface aerators and oil skimming facilities. This in turn is passed through a third and smaller pond that has a surface aerator. The discharge from this aerated pond system is introduced into a splitter box where the water can be recycled for reuse or discharged. The total discharge from this facility averages 390 gallons per minute.

GREAT WESTERN SUGAR COMPANY

This beet sugar refinery is in Billings and is the largest refinery operated by the Great Western Sugar Company. The company processes approximately 4,500 tons of beets per day and the campaign runs between four and five months during the year. There are two discharge points from this factory. The first discharge point at the front of the factory consists of the condenser cooling water that will average about 7,000 gallons per minute. This water is discharged to a storm sewer system that in turn discharges in Yegen Drain. Yegen Drain then empties into the Yellowstone River. The second discharge point is what is referred to as the back yard discharge. This water consists of that which is used for transportation of the beets through the beet flumes. Each ton of beets processed produced approximately 300 to 500 gallons of water that has to be treated and discharged or reused.

The water used for transporting the beets is treated in a clarifier system that removes the larger particles of mud and organic material that is collected on the beets. The water from the clarifier unit which consists of 4-6% solids is then pumped to a settling (mud) pond; after settling, water is returned to the clarifier-flume system for reuse with excess water routed to the treatment ponds. As a result, an inadequate volume of sludge develops in the treatment ponds to afford a disposal problem. The mud ponds are either periodically dredged or new ponds constructed; the settled refuse is transported to landfills or to remote areas at the factory site. This material does not enter Yegen Drain nor the Yellowstone River.

The treatment ponds consist of two large and aerated ponds with 9-50 horsepower, surface aerators. The final settling pond which has a surface area of about one-half acre provides the final treatment. The discharge from this system to Yegen Drain and then the Yellowstone River averages approximately 450 gallons per minute throughout the campaign.

The effluent limitations on the permit for the 1974-1975 campaign will be further restricted for the 1975-1976 campaign. Additional treatment facilities will have to be provided to meet the effluent limitations imposed during this next campaign. As a result, Great Western is scheduled to tie into the City of Billings sewer system at the start of the 1976-1977 season.

MONTANA POWER COMPANY

The Montana Power Company operates two power plants in Billings. The smaller plant commonly referred to as the "Byrd" plant is an oil operated unit and operates only when demands necessitate its operation. The plant is rated at 8 megawatts and the only discharge from this plant is a once through cooling water system. Approximately one million gallons per day are discharged when this plant is operating. The large plant which operates on a continual basis is referred to as the "Corette" plant. This plant is rated at 80 megawatts and has two points where wastewater is discharged. The larger discharge point is the once through cooling water where approximately 35 million gallons of water is discharged daily. The Corette plant is a coal fired operation and the ash from the boilers is mixed with water and transported to an ash disposal pond. In this pond the particulate settles and the clear water is discharged through the second point of discharge. The amount of discharge from this point is less than 50,000 gallons per day. The domestic sewage from the facilities at these power plants is disposed of through septic tanks and drainfield systems.

MONTANA SULPHUR AND CHEMICAL COMPANY

This chemical company uses waste products from the Exxon Company USA refinery for their raw materials. They produce sulphur and hydrogen sulfide gas that are shipped to different points in the United States. The discharge from this facility consists of once through cooling water and amounts to approximately 500 gallons per minute. The discharge enters a drain ditch that in turn discharges into a slough area. It is doubtful that the discharge reaches the Yellowstone River.

EMPIRE SAND AND GRAVEL COMPANY

This company is engaged in the manufacture of gravel and sand materials that are sold to local contractors and contracting companies. A new system has been installed that consists of a clarifier which removes a considerable amount of the silt that previously was discharged. The wastewater from the washing facility at the present time enters a settling pond where the material settles out and the effluent is discharged into Five Mile Creek which eventually discharges into the Yellowstone River. The total amount of discharge from this facility when it is operating is approximately 2,000 gallons per minute.

CENEX

This refinery which is the third refinery in the Billings-Laurel area is located in Laurel and produces gasoline and light and heavy fuel oils and road oils. The treatment system for the process water consists of an API separation unit that skims oil, an aerated pond that accomplishes biological treatment, a final settling pond, and discharge to the Yellowstone River. The total amount of discharge from this facility is approximately 350 gallons per minute. The water use for cooling purposes at the CENEX refinery is cooled by the use of cooling towers and recirculated. Domestic sewage is disposed of through septic tanks and subsurface drainfields.

BURLINGTON NORTHERN SEWER - LAUREL

This 21-inch sewer line transports wastewater from the Burlington Northern yards and the UTLX tank car company located near Laurel. The waste from the Burlington Northern facilities are discharged into an oil separation facility from where the discharge enters the drain line which eventually empties into the Yellowstone River. The facilities at the UTLX tank car company consist of an oil skimming system that uses baffled tank cars. The discharge from this skimming system enters the Burlington Northern drain line. This sewer line is subjected to large amounts of subsurface oil at certain times of the year during rises in the subsurface groundwaters. This problem will be mentioned later in this report as non-point discharges. The discharge from this drain will vary between 500 and 800 gallons per minute on a year around basis.

BURLINGTON NORTHERN RAILROAD - LIVINGSTON

The Burlington Northern Railroad in Livingston has over the past years had an oil discharge problem from the railroad facility. The company has constructed an oil removal facility that consists of an air flotation system, chemical feed equipment for flocculation chemicals and pH control, and a discharge directly to the Yellowstone River. Some difficulties have arisen in the operation of this plant, but it appears to be producing an acceptable effluent at this time.

AGRICULTURAL DISCHARGES

Extensive information regarding agricultural discharges is not readily available, but a variety of such discharges are known to be present within the basin. Such discharges include irrigation return flows, animal confinement facilities, and runoff from range and cultivated land. The information contained in this report has been compiled from data collected in conjunction with the Montana Pollutant Discharge Elimination System and from limited field observations. The permit requirements for agricultural discharges vary with the particular discharge and thus the requirements are stated on the waste discharge permit.

Table 3

Summary of Municipal Discharge Information**

Municipality	Type of Treatment	Design Pop. Equiv.	Pop. Served	Average[1] Daily Discharge	Type of Discharge	Receiving Water	State Priority List*
Red Lodge	Lagoon/6 cells 20 acres	2,000	1,840	2.5	Continuous	Rock Creek	1
Absarokee	Lagoon/4 cells 1.5 acres	150	600	0.75	Continuous	Rosebud	1
Yellowstone Boys Ranch	Lagoon/2 cells 1.57 acres	157	175	0.0	NA	NA	4
Edgar	Lagoon/2 cells 2.6 acres	260	210	----	Intermittent	Clark Fork-Yellowstone	4
Park City	Lagoon/2 cells 4 acres	400	430	0.0	NA	NA	4
Fromberg	Lagoon/1 cell 4 acres	400	364	0.02	Continuous	Clark Fork-Yellowstone	3
Bridger	Lagoon/1 cell 9 acres	900	824	0.04	Continuous	Clark Fork-Yellowstone	4
Bearcreek	Settling tank	----	20	0.006	Continuous	Bear Creek	2
Joliet	Aerated Imhoff tank with chlorination	600	412	0.35	Continuous	Rock Creek	4

** See Appendix D for further information on permit numbers and compliance schedules.

Table 3
(continued)

Municipality	Type of Treatment	Design Pop. Equiv.	Pop. Served	Average[1] Daily Discharge	Type of Discharge	Receiving Water	State Priority List*
Roberts	Lagoon/1 cell 3.4 acres	340	200	0.20	Continuous	Rock Creek	1
Belfry	Lagoon/2 cells 4.5 acres	450	250	0.0	None	NA	4
Billings	Primary activated sludge-secondary under construction	120,000	61,600	12	Continuous	Yellowstone River	1
Laurel	Primary activated sludge	4,500	4,450	1.2	Continuous	Yellowstone River	1
Columbus	Lagoon/2 cells 16 acres	1,600	1,170	0.09	Seasonal	Yellowstone River	4
Big Timber	Lagoon/1 cell 18 acres	1,800	1,590	0.15	Continuous	Boulder River	2
Livingston	Primary activated sludge	13,500	8,800	2.6	Continuous	Yellowstone River	1
Gardiner	Aerated lagoon 2 cells/4.1 acres	3,000	600	0.0	None	NA	4

[1] Flow in MGD when discharging.

* 1) Grant Project Underway; 2) Scheduled for Step 1 Grant Funding in FY 1976; 3) Too low on Priority List to receive funding at this time; 4) Not on Priority List.

Table 4

Summary of Municipal Sewage Discharge Data
(Data from MT Water Quality Bureau)

Municipality	Location (1)	Date	Flow MGD	BOD mg/1	BOD % Red	TSS mg/1	TSS % Red	pH S.U.	Fecal Coliform colonies/100 ml	NO_3 mg/1	PO_4 mg/1
Billings WWTP	01N 26E 26BB	2/4/75	10.0	96.0	--	73.0	--	7.3	<100	-----	-----
Laurel WWTP	02S 24E 15DD	7/31/74	1.74	27.8	18	60.0	64		2.85×10^5	-----	-----
Bridger SL	06S 23E 22CB	12/20/75	0.04	19.0	90	55.0	75	7.5	1.05×10^5	-----	-----
Joliet SL	04S 22E 15	9/28/73	0.08	76	--	----	--	---	9.6×10^4	2.7	9.0
Roberts SL	05S 21E 32	9/27/73	0.20	142	--	----	--	7.2	1.5×10^3	0.73	0.50
Red Lodge SL	07S 20E 23	9/27/73	0.90	87	--	----	--	7.3	$<10^3$	0.25	0.50
Columbus SL	02S 20E 27CB	10/3/74	0.02	77	80	35	84	8.3	1.6×10^4	0.24	13.0
Absarokee SL	04S 18E 01AB	12/20/74	0.18	23	70	----	--	7.5	2.15×10^5	-----	-----
Big Timber SL	01N 14E 14AB	10/1/74	0.29	28	87	8.0	36	---	1.2×10^6	0.09	0.49
Livingston WWTP	02S 10E 07	10/1/74	2.5	54	54	48	6.0	7.2	7.2×10^6	0.22	0.05
Gardiner SL	09S 08E 22BB	11/18/74	----	42.0	91	----	----	7.5	2.75×10^3	15	2.9

(1) - See Appendix A
WWTP - Wastewater Treatment Plant
SL - Sewage Lagoon

Table 5

Summary of Industrial Waste Information **

Name of Industry	Type of Treatment	Type of Discharge	Receiving Water	Average Daily Discharge
Montana Power Co. (Byrd) Billings, MT	None	Continuous Cooling Water	Yellowstone River	1.0 MGD
Montana Power Co. (Corette) Billings, MT	Settling Ponds	Continuous Cooling Water & Ash Pond Discharge	Yellowstone River	35.0 MGD
Montana Sulfur & Chemical Co. Billings, MT	None	Continuous Cooling Water	Drain Ditch- Yellowstone River	0.7 MGD
Empire Sand and Gravel Co. Billings, MT	Settling Pond	Continuous Wash Water	5 Mile Creek- Yellowstone River	2.9 MGD
Exxon Company U S A Billings, MT	Oil Skimmer	Continuous Cooling Water	Yellowstone River	30 MGD
Exxon Company U S A Billings, MT	API Separator Settling Ponds Aeration Facility	Continuous Process Water	Yellowstone River	2.0 MGD
Continental Oil Company Billings, MT	Oil Skimmer Aeration Facility Settling Ponds	Continuous Process Water	Yegan Drain- Yellowstone River	0.6 MGD
Great Western Sugar Co. Billings, MT	None	Continuous Condenser Water	Yegan Drain-	10.1 MGD

Table 5
(continued)

Name of Industry	Type of Treatment	Type of Discharge	Receiving Water	Average Daily Discharge
Great Western Sugar Co. Billings, MT	Clarifier Aeration Ponds Settling Pond	Continuous Process Water	Yegan Drain-Yellowstone River	0.6 MGD
Cenex Oil Refinery	A&I Separator Aeration Ponds Settling Ponds	Continuous Process Water	Yellowstone River	0.50 MGD
Burlington Northern Sewer Laurel, MT	Oil Separation Facility Oil Skimmers	Continuous Wash Water	Yellowstone River	0.9 MGD
Burlington Northern Livingston, MT	Air Flotation Floculation pH Control	Continuous Wash Water	Yellowstone River	0.2 MGD

** See Appendix D for further information on permit numbers and compliance schedules.

Irrigation return flows are subject to MPDES permit requirements, if a single man-made or man-maintained point source discharge drains 3,000 or more irrigated acres. Those irrigation systems in the Upper Yellowstone Basin having applied for an MPDES permit are summarized in Table 6.

Animal confinement facilities in the Upper Yellowstone basin are of three types: swine, cattle, and fish. A description of the animal confinement facilities that have applied for or received MPDES permits in the Upper Yellowstone River basin are included in the following discussion.

BLUEWATER FISH HATCHERY

The hatchery is located east of Fromberg on Bluewater Creek. Presently, there are no waste treatment facilities at the hatchery. The source of water for the hatchery is Bluewater Springs. The springs provide about 2,500 gallons per minute of water. There is no recirculation and thus the discharge from the hatchery is also about 2500 gpm. The discharge is to Bluewater Creek, a perennial tributary of the Clarks Fork Yellowstone River. The hatchery produces an estimated 82,000 lbs of fish per year. EPA has not as yet published effluent limitations and guidelines for fish hatcheries.

CARL JOHNSON FEED LOT - F-28-B issued November 26, 1973

Mr. Carl Johnson currently maintains a beef feeding operation having capacity for approximately 600 cattle and covering approximately 3 acres. The location of this operation is in the SE¼, SE¼, Sec. 32, T2N, R27E of Yellowstone County approximately 8 miles northeast of Billings. Surface runoff is contained in a holding pond constructed in a coulee which originates in the feeding area. Waste material is removed from the feeding area twice yearly and disposed of on 200 acres of agricultural land. Liquid waste in the holding pond will evaporate or will be pumped onto surrounding land.

JAMARTOM RANCHES, INC. - F-30-B issued December 5, 1973

Mr. Thomas W. Fellows currently operates an animal confinement facility having capacity for approximately 500 beef cattle encompassing 5.0 acres. The operation is located in the SE¼, Section 19, T3N, R15E of Sweetgrass County. Due to the topography of the area, surface runoff is diverted onto adjacent agricultural land and should not reach state waters. Waste material which accumulates on the surface of the feeding area is periodically removed and disposed of on agricultural land.

FRED ZEILER FEEDLOT - F-14-B issued June 21, 1973

Mr. Fred Zeiler operates a confined feeding operation having a capacity for 700-800 cattle for fattening and 1,000 to 1,200 for wintering. This operation is located in the

Table 6

IRRIGATION DISTRICTS IN UPPER YELLOWSTONE BASIN

APPLICANT NAME	LOCATION	PERMIT NO.	NUMBER OF IRRIGATED ACRES	ESTIMATED RETURN FLOW IN ACRE-FEET PER YEAR
Canyon Creek Ditch Company	Between Laurel & Billings	MT-0022861	5,500	-----
Billings Bench Water Association	Laurel	MT-0022837	18,000	6,000

S½, NW¼, Section 28, T1S, R25E, Yellowstone County, approximately 7 miles northeast of Laurel. A retention pond has been built with a capacity of 462,825 gallons which is considered adequate for this operation. Manure will be hauled and spread over 320 adjacent acres of farm land. Liquid runoff is ditched onto the land as irrigation water. There will be no discharge of liquid wastes into surface water. There are no wells on this property, but some groundwater is known to exist within eight feet of the surface. Where the water table is known to be high, the surface is built up with soil to assure adequate separation of the water table and the bottom of the disposal facilities.

BANGERT FEEDLOT - F-24-B issued August 28, 1973

Mr. Laurence Bangert has constructed a confined beef feeding operation of approximately 10 acres in size west of Belfry, Montana located in the SW¼, NW¼, Section 15, T8S, R22E of Carbon County. Surface runoff from the feeding area is contained in a semi-circular holding pond on the south edge of the feedlot. Waste material is removed from the control facility as necessary to maintain adequate storage.

RAY ZEILER FEEDLOT - F-24-B issued September 13, 1973

Mr. Ray Zeiler operates a confined livestock feeding operation having a capacity for approximately 1,000 head of cattle. This operation is located 1½ miles southwest of Billings, Montana in the NE¼, SE¼, Section 18, T1S, R26E, of Yellowstone County. A holding pond retains the surface runoff from the feeding area due to rainfall or snow melt. The runoff material will be spread on agricultural land owned by Mr. Zeiler. To minimize the odor problem, Mr. Zeiler has a waste management program which consists of bedding the lots with straw and frequent removal and disposal of the waste material which accumulates on the feedlot surface.

DAVE SHAULES FEEDLOT - MT-0029004 issued May 24, 1974

Mr. Dave Shaules currently operates a confined livestock feeding operation having a capacity for 900 feeder cattle. This operation encompasses approximately 3 acres and is located in the SE¼ of the SE¼ of Section 32, T2N, R27E northeast of Billings, Montana in Yellowstone County. Extraneous drainage is prevented from reaching the feeding area by an irrigation canal located on the north and west sides of the feeding area. Minimal runoff should result from the extremely flat topography and any runoff which would occur would be carried by a separate irrigation ditch to agricultural land under their control. This runoff would be contained on this agricultural land with little possibility of ever reaching state waters. Waste material is removed from the feeding area twice per year and spread on agricultural land owned by the operator.

HINDMAN HOG COMPANY - MT-0029011 issued July 3, 1974

Mr. James Hindman has operated since 1967 a total confinement swine operation having a maximum capacity of approximately 900 animals. This operation is located in the NW¼, of the SE¼ of Section 20, T5S, R23E of Carbon County, approximately one-half mile south of Fromberg, Montana. This confined swine operation consists primarily of a farrowing operation as the pigs are sold as feeders instead of being finished out at that location. The confinement building is divided into three sections. The building includes a gestation section where sows are held for approximately 30 days prior to farrowing, a farrowing section and a nursery unit where the young pigs are held until they are sold. Waste material which is produced within the building drops through the slatted floors into liquid manure pits located beneath the building. These manure pits are sized according to the number of animals within that section and the total amount of waste material which will be produced. Waste material is then removed on a weekly basis from the manure pit and spread on adjacent agricultural land. The waste material is not spread within one-half mile of any other residences unless it is incorporated with the soil immediately.

GILBERT AMEN ANIMAL CONFINEMENT FACILITY - MT-0029012 issued July 10, 1974

Mr. Gilbert Amen currently operates a confined livestock feeding operation having a capacity for approximately 400 feeder cattle located in the SW¼, SE¼, of Section 10, T1S, R25E of Yellowstone County west of Billings, Montana. Extraneous drainage is prevented from reaching the feeding area due to the extremely flat topography. Minimal runoff should result from the area and any runoff which would occur is routed onto adjacent agricultural land. This runoff is contained on this property with little possibility of ever reaching state waters. Waste material is removed from the feeding area at least once per year and spread on agricultural land owned by the operator.

LARRY STALEY ANIMAL CONFINEMENT FACILITY - MT-0029013 issued July 17, 1974

Mr. Larry Staley operates a confined livestock feeding operation having a capacity for approximately 950 feeder cattle. This operation is located in the SW¼ of the SW¼ of Section 18, T1S, R25E of Yellowstone County, 9 miles west of Billings, Montana. Extraneous drainage is prevented from reaching the feeding area due to the flat topography. Minimum runoff should result from the area and any runoff which would occur is routed onto adjacent agricultural land. This runoff should be contained on the owner's property with little possibility of ever reaching state waters. Waste material is removed from the feeding area at least once each year and spread on adjacent agricultural land owned by the operator.

JAMES L. BAKER CONFINED SWINE OPERATION - MT-0029016 issued July 30, 1974

Mr. James Baker currently maintains a confined swine operation having a capacity for approximately 300 head. This feeding operation is located in the NW¼ of the NW¼ of Section 28, T2S, R23E of Stillwater County near Park City, Montana. The swine are fed on concrete floors which are so constructed that they drain to a cleaning gutter. Waste material which is produced flows or is scraped to the cleaning gutter located along the south side of the feeding area. The concrete floor and gutter are cleaned at least weekly and the waste material which is in the pits is removed and spread on surrounding agricultural land. During periods of inclement weather when field application of the waste material is impractical, the material is piled in a storage area which has been constructed to prevent the discharge of any waste material to state waters. Any runoff of manure from this area is contained in a retention pond located adjacent to the storage area. The liquid which may accumulate in the retention pond is usually disposed of through evaporation, or when necessary pumped out and disposed of through the use of a honey wagon.

WEBER AND SONS - MT-0029022 issued October 16, 1974

Weber and Sons currently operates an animal confinement facility having a capacity for approximately 650 head feeder cattle located south of Billings in the NW¼, NE¼, Section 19, T1S, R26E of Yellowstone County. Extraneous drainage is prevented from reaching the feeding area due to the extremely flat topography and the physical barrier of a feeding alley. Minimal runoff should result from an area such as this and any runoff which might occur would be routed southeast onto adjacent agricultural land. Waste material is removed from the feeding area at least once per year and spread on agricultural land owned by the operator.

EBEN HUNGTINGTON - MT-0029027 issued October 30, 1974

Since 1955, Mr. Eben Huntington has operated an animal confinement facility having capacity for approximately 2,000 swine. This operation is located in the SW¼, Section 10, T1S, R27E of Yellowstone County approximately seven miles southeast of Billings, Montana. This confinement facility consists of a farrowing unit, nursery unit, and finishing unit. Waste material produced in the farrowing and nursery unit drops through slatted floors into liquid manure pits located beneath each building. These pits provide sufficient storage to retain in excess of 120 days waste production. Waste material in the finishing unit is pushed onto a concrete slab where it is loaded onto a spreader for disposal. The waste material which accumulates in the liquid manure pits is likewise periodically removed and disposed of on adjacent agricultural land.

CARBON COUNTY CATTLE COMPANY - issued August 12, 1974, No. MT-0022187

Mr. Buster Stoddard currently operates an open confinement, commercial cattle feeding operation with a capacity for approximately 6,000 head of cattle. This facility is located in the NW¼, Section 24, T4S, R21E, Carbon County. Extraneous drainage from above the feeding operation is prevented from reaching the feeding area by a number of reservoirs and by the county road. Existing control facilities consist of collection ditches and a retention pond. Drainage from the proposed expansion will also be contained in this retention pond. Liquid can be pumped into an adjacent irrigation ditch and spread on agricultural land. Manure is removed from the feeding area periodically throughout the year and hauled directly to the disposal areas or stockpiled for later disposal. Drainage from this stockpile area goes into the retention pond.

PATTON-DAVIDSON CATTLE FEEDERS - issued October 30, 1974 No. MT-0023299

Mr. Richard M. Davidson, President, currently operates an open confinement, commercial cattle feeding operation having a total capacity for approximately 7,400 animals. The operation is located in the NE¼ of Section 7, T3S, R22E of Stillwater County approximately seven miles west of Park City, Montana. Extraneous drainage does not come in direct contact with significant livestock waste. The only wastewater generated will then be the precipitation which falls directly on the feedlot surface. The contaminated surface runoff is currently contained through a series of diversions and retention structures. These ponds, with some cleaning and modification, will provide sufficient capacity to retain all runoff which can be expected following a 10-year, 24-hour rainfall event. Waste material which accumulates in the retention ponds will be removed as necessary to maintain maximum storage capacity. Waste material which accumulates on the feedlot surface will be removed at least twice per year and hauled directly to adjacent agricultural land or is stockpiled for later removal and disposal.

Mr. Davidson also proposes expansion of the animal confinement facility. This expansion would be located in the NW¼, Section 8, T3S, R22E of Stillwater County. This would increase the feeding area by approximately five acres and the capacity by approximately 1,000 head. Runoff would be contained in a retention pond located to the south of the feeding area.

PEAVEY MONTANA FEEDLOTS (PEAVEY COMPANY) - No. MT-0023442 issued December 13, 1974

This animal confinement facility is an open confinement, commercial cattle feeding operation having a total capacity for approximately 9,500 animals. The operation is located in the NE¼, Section 1, T2S, R24E of Yellowstone County approximately three miles northeast of Laurel, Montana. Extraneous drainage from above the approximately 80-acre feeding area does not reach the feedlot itself due to the relatively flat topography, so the only wastewater generated will be from precipitation which falls directly on the feedlot surface. Most of this runoff is directed to the southwest corner of the feeding area where it is contained in a large retention pond. Approximately 1,000 acres of agricultural land are available for the disposal of the waste material which would be removed from the feedlot surface.

EARL R. SPENCER FEEDLOT - MT-0022624 issued October 30, 1974

Mr. Earl R. Spencer currently operates an open confinement beef feeding operation having a capacity of approximately 1,500 animals. The operation is located in the NW¼, SW¼, Section 16, T5S, R23E of Carbon County, approximately one-half mile northeast of Fromberg, Montana. Due to the relatively flat topography of the area, extraneous drainage does not reach the feedlot itself. Therefore, the only wastewater generated will be from precipitation which falls directly on the feedlot surface. This contaminated surface runoff is contained in two small holding ponds located below the feeding area. Any discharge from the facility would be to the Clarks Fork of the Yellowstone River. Waste material which accumulates in the retention pond will be removed as necessary to maintain maximum storage capacity. Waste material which accumulates on the feedlot surface is removed approximately twice per year and disposed of on surrounding agricultural land.

VALE CREEK RANCH - MT-0022292 issued August 12, 1974

Mr. Max E. Thornton operates a commercial cattle feeding operation located in the SW¼, Section 2, T2S, R26E of Yellowstone County, approximately 7 miles south of Billings, Montana. The feeding operation having a capacity for approximately 4,000 head of cattle, is located near the top of a ridge, threby nearly eliminating extraneous runoff from reaching the feedlot. All runoff from the confinement area and silage drainage are diverted into holding ponds. If necessary, this liquid waste can be removed and disposed of in 6,000 acres of agricultural land. Solids which will accumulate in the control facility will be periodically removed and spread on adjacent agricultural land. Manure is removed from the feedlot surface twice per year and hauled to disposal areas.

WESCHENFELDER FEEDLOT (EAST LOT) - MT-0023507 issued September 17, 1974

Mr. Henry Weschenfelder currently maintains an open lot, confined beef feeding operation encompassing approximately nine acres, located in the SW¼ of the SE¼ of Section 21, T2S, R23E of Stillwater County, approximately 1¼ miles northeast of Park City, Montana. Extraneous drainage does not contribute significant runoff into the feedlot due to the relatively flat topography of the area. The contaminated surface runoff is contained in a retention pond which has been constructed immediately south of the feeding area. Any discharge from the facility would be to unnamed drainages to the Yellowstone River approxiamtely four miles away. Waste material from the feedlot surface is removed approximately three times per year and disposed of on surrounding agricultural land. Approximately 600 acres of agricultural land is available for waste disposal.

WESCHENFELDER FEEDLOT (MAIN LOT) - MT-0023493 issued September 17, 1974

Mr. Henry Weschenfelder currently operates an open lot confined beef feeding operation having a capacity for approximately 3,500 head. The operation is located in the NW¼ of the NE¼ of Section 29 and the SW¼ of the SE¼ of Section 20, T2S, R23E of Stillwater County approximately one-half mile northeast of Park City, Montana. Due to the relatively flat topography of the area, extraneous drainage from above the approximately 20-acre feeding area does not reach the feedlot itself. The contaminated surface runoff is contained in a retention pond located directly south of the feeding area. The retention pond has sufficient capacity to retain all runoff which can be expected from a 10-year, 24-hour rainfall event or equivalent moisture for their locale. Any discharge from the facility would eventually reach the Yellowstone River approximately four miles away. Waste material is removed from the feedlot surface approximately three times a year and spread on surrounding agricultural land. Should excessive waste material accumulate in the retention pond, it will likewise be removed and disposed of on this agricultural land.

NON-POINT SOURCES

Little consideration has been given to non-point sources in the past because of the difficulty in their identification. Pollutants contributed by these sources within the basin may be significant. Although any one specific area of non-point waste may have a minor effect, several such sources on a stream may produce water quality problems. Non-point pollution arises from a variety of activities, including agriculture, runoff from urban areas, construction projects, inadvertent spills, and natural phenomena.

Irrigation return flows from numerous small areas can exhibit this cumulative effect on state waters. These flows are higher in total dissolved solids and sediment and contain more nutrients and pesticides than water applied to the field.

Runoff from pasture lands may carry animal wastes and sedimentation to state waters. A number of pastures in the basin use streams as a boundary. In many cases in these pastures there is no vegetation on the stream bank or in the immediate floodplain due to livestock concentrating in these areas. As a result, there is no protection from erosion due to irrigation, storm runoff, and high water. The use of lands in the basin that exhibit sparse vegetation due to fragile soils for pastures tends to amplify stream sediment in these areas.

Runoff from agricultural land where saline seep has been allowed to develop presents another potential non-point source pollution problem. Although only a few areas within the Upper Yellowstone River Basin have been defined strictly as saline seep areas, it is expected that the on-going studies will identify additional seep areas.

Runoff from cultivated lands may present potential non-point pollution problems from fertilizers, pesticides, dissolved salts, and sediment. Increased demand for food causes an increased demand for farm products and this in turn leads to the use of more fertilizers and pesticides to increase the yield on agricultural lands. Removal of brush and trees from stream banks and the floodplain to increase stream access, control weeds, and increase the amount of cropland causes increased erosion.

Community storm drain systems present another non-point pollution source due to a variety of hazardous materials including: oil and grease, coliforms, biologically oxidizable material, suspended solids, plus various toxic metals. The EPA has to date excluded storm drainage from the NPDES program and they have been excluded from the MPDES permit program. The impact of these discharges on water quality in the Upper Yellowstone River Basin is probably significant.

Construction projects and stream bank disturbances are important non-point pollution problems. Coal developments with this type of activity are expected to increase due to energy related development in the Upper Yellowstone River basin. Increases in the population projected to occur in the basin will increase the number of inadvertent spills of toxic or deleterious materials into surface or groundwater systems.

Pollution of groundwater from non-point sources is present in a minimal amount in various areas of the basin. Localized areas of groundwater pollution result from seepage of sewage lagoons and drain fields. Saline seep areas may be considered as resulting from polluted ground-water. These areas occur in many portions of the basin, the most note-worthy being an area north of the Yellowstone around Broadview (Plate 1). Due to practices of discarding oil in the past, a number of places within the basin have polluted groundwater, most notable is the Laurel-Billings area.

In view of the lack of extensive information on non-point sources, any rating of relative priorities of these sources can only be developed as to their suspected impact on receiving waters and to their future potential. With this constraint the following is the non-point priority list for the basin:

(1) agricultural non-point discharges,

(2) storm drains and urban runoff,

(3) construction projects (subdivisions, roads, bridges, riprapping etc.),

(4) accidental discharges (spills), and

(5) natural non-point sources.

Hopefully the 208 program for the area will update and refine this priority list.

In addition to the obvious point and non-point source problems described previously, attention has been recently focused upon the problem of flooding in the Upper Yellowstone River Basin, particularly in the Billings area, and its potential for influencing water quality. This aspect has been accentuated in recent years due to the unique occurrence of two consecutive high water years in 1974 and 1975 and associated floods. Below is a statement from Representative Esther G. Bengtson of Shepherd (House District 59) that generally describes this problem; this statement was read to the public hearing of the Upper Yellowstone, Water Quality Management Plan (Ref. 9).

"Upon reviewing the Water Quality Inventory and Management Plan of the Upper Yellowstone River Basin in Montana (preliminary draft) made by the Water Quality Bureau of the State of Montana, it was discovered that there are a total of at least fifteen basin-wide water quality related studies being conducted.

These studies are being made to fulfill the following objectives: 1. to determine the water characteristics of all natural and wastewaters, 2. to determine what factors, both natural and manmade, affect the quality of the water and 3. to develop a management strategy for maintaining and enhancing the quality of waters in the basin. Included in their investigation were types of water pollution which affected water quality. These types of pollution sources included municipal discharges, industrial discharges, agricultural discharges and non-point sources of pollution.

Not one of these studies included flooding as a factor that should be considered as having an effect upon water quality. Certainly water quality is affected by flooding. Flooding affects water quality by increasing waste deposits--not only from industrial, municipal and domestic users but also from agriculture during flood periods. This is to say nothing about destroying fish and wildlife habitat and more importantly to our area, the destruction of valuable agricultural land.

At the hearing held October 21 in Billings, at which time the plan was discussed, I urged that present and future studies on water quality and management include flooding as a contributing factor to water quality and that this factor be managed as much as any other factor affecting water quality.

It is not too soon to be thinking about the flood season on the Yellowstone River in 1976. Unless we incorporate the study of flooding into all of our water studies in Montana, we are not covering all points on water quality and most importantly not reaching any solutions to a most serious problem in Montana---flooding on our rivers and streams."

VII. SURFACE WATER RESOURCES

GENERAL FEATURES

The Upper Yellowstone River basin contains eight sub-basins. The major streams in these sub-basins are:

1. Yellowstone River mainstem from the Yellowstone National Park boundary to just below the confluence of Bridger Creek.

2. Shields River.

3. Boulder River.

4. Sweet Grass Creek.

5. Yellowstone River mainstem from just below the confluence of Bridger Creek to the confluence of the Clark Fork of the Yellowstone River.

6. Stillwater River.

7. Clarks Fork Yellowstone River.

8. Yellowstone River mainstem from the confluence of the Clarks Fork Yellowstone River to the confluence of Pryor Creek.

The U. S. Geological Survey has maintained several stream flow gaging stations in the basin at the present time. Sixteen of these are active. An examination of stream flow data available for the streams and rivers in the Upper Yellowstone River basin shows that peak flows generally occur from mid-June to mid-July due to snowmelt from mountain snow pack. The melting of these mountain snow packs contributes in a large way to the stable and usually plentiful runoff experienced in most years. This generally provides an abundance of water in the major drainages during mid-summer when water needs are the greatest. The so-called "chinook" winds of the northern Rockies can produce runoff conditions in mid-winter in the lower valleys and the plains areas of the basin. Yellowstone Lake in Yellowstone National Park provides a large natural reservoir covering 142 square miles which serves to distribute the outfall to the river throughout the summer months without artificial regulation. West Rosebud Creek is regulated by Mystic Lake and Red Lodge. Table 7 summarizes stream flow information and data for several streams in the Upper Yellowstone River basin for which continuous discharge data is available (Ref. 1 and 5). Figure 3 is a schematic diagram of surface waters in the basin. Figure 4 is a graph of average monthly mean discharge in cubic feet per second for the gaging stations at Corwin Springs and Billings on the Yellowstone River (Ref. 1-4).

Table 7

SUMMARY OF STREAM FLOW INFORMATION FROM GAGED STREAMS IN THE UPPER YELLOWSTONE BASIN

Station Designation	Station Location	Drainage Area (sq mi)	Years of Record	Maximum Flow (cfs)	Minimum Flow (cfs)	Avg Annl Flow (cfs)	7-dy, 10-yr Low Flow (cfs)
Gardiner River nr Gardiner	44° 59' 35' 110° 41' 25"	None	10/38 9/72	2,080	35	220	70
Yellowstone River @ Corwin Springs	45° 06' 43" 110° 47' 37"	25	8/89-11/93 9/10-current	32,000	389	3103	490
Mill Creek nr Pray	45° 21' 21" 110° 37' 12"	148	3/51-9/55	2,300	3.9	128	---
Yellowstone River nr Livingston	45° 35' 50" 110° 33' 55'	950	5/97-12/05 8/28-9/32 10/37-current	30,600	590	3732	---
Shields River nr Wilsall	46° 06' 35" 110° 36' 46"	88	5/35-9/57	1,770	-----	60.3	---
Shields River @ Clyde Park	45° 53' 10" 110° 37' 05"	543	3/21-9/23 4/29-12/32 2/34-9/67	4,500	1.8	159	---
Brackett Creek nr Clyde Park	45° 51' 57" 110° 41' 11"	60	3/21-9/23 4/34-9/57	1,400	0.5	27.8	---
Bangtail Creek nr Chadborn	45° 49' 08" 110° 34' 09"		3/23-6/23	88	1.5	------	---
West Fork Boulder R. nr Bruffeys		94	4/04-8/10	1,610	20	------	---
West Fork Boulder R. @ McLeod	45° 39' 44" 110° 06' 49"	137	5/07-7/14	1,990	------	------	---
Boulder River nr Contact	45° 33' 17" 110° 12' 00"	226	5/10-9/16 4/29-8/29 10/50-9/69 10/70-current	5,590	4.2	380	39
Boulder River @ Big Timber	45° 50' 03" 109° 56' 17"	523	4/47-12/53 3/35-current	9,840	10	602	34
Sweet Grass Creek abv Melville	46° 09' 15" 110° 05' 15"	64	8/13-12/24 4/ -9/69	2,270	0.7	86.4	4.5
Stillwater River @ Nye	45° 26' 16" 109° 47' 27"	337	10/69-current	6,390	23	563	---
East Rosebud Crk nr Roscoe	45° 20' 52" 109° 29' 49"	125	10/20-6/21 10/21-9/24	1,980	4	-------	---
West Rosebud Creek nr Roscoe	45° 14' 35" 109° 43' 50"	52	9/65-current	1,470	2.5	132	---
Rosebud Creek nr Absarokee	45° 29' 12" 109° 27' 19"	394	4/35-9/69	5,790	31	407	---
Stillwater River nr Absarokee	45° 33' 04" 109° 23' 12"	975	7/10-9/14 3/35-current	12,000	58	952	123

Table 7
(Continued)

Station Designation	Station Location	Drainage Area (sq mi)	Years of Record	Maximum Flow (cfs)	Minimum Flow (cfs	Avg Annl Flow (cfs)	7-dy, 10-yr Low Flow (cfs)
Clarks Fork Yellowstone nr Belfry	45° 00' 40" 109° 04' 00"	10	7/21-current	10,900	32	944	82
Big Sand Coulee @ MT/WYO line	45° 00' 17" 109° 03' 29"	None	5/73-current	------	----	----	----
Silver Tip Creek nr Belfry	45° 09' 32" 108° 58' 31"	65	10/67-current	1,100	0.0	2.5	----
Bluewater Creek nr Bridger	45° 19' 54" 108° 48' 04"	28	3/60-9/70	2,650	19	28.2	----
Bluewater Creek @ Fromberg	45° 27' 02" 108° 54' 02"	53	6/61-6/64	500	4.4	----	----
Clarks Fork Yellowstone @ Fromberg	45° 23' 47" 108° 53' ~~41"~~	800	6/04-11/04 4/06-11/12 3/13-12/13	12,700	----	1380	----
Clarks Fork Yellowstone @ Edgar	45° 27' 58" 108° 50' 35"	890	7/21-9/69	10,900	36	1044	----
Clarks Fork Yellowstone nr Silesia	45° 30' 48" 108° 49' 41"	950	10/69-current	11,800	140	1235	----
Rock Creek blw Glacier Lake	45° 00' 15" 109° 31' 56"	4	9/60-9/64	90	0.0	----	----
Rock Creek nr Red Lodge	45° 07' 47" 109° 16' 51"	124	4/32-12/32 5/34-current	3,110	14	172	20
West Fork Rock Crk blw Basin Crk	45° 09' 01" 109° 18' 46"	63	7/37-10/56	90	----	----	----
West Fork Rock Creek nr Red Lodge	45° 09' 16" 109° 17' 43"	67	4/32-12/32 5/34-9/44	1,850	2.5	66.5	----
Red Lodge Crk abv Cooney Reservoir	45° 26' 16" 109° 15' 11"	143	5/37-current	2,260	----	----	----
Red Lodge Crk blw Cooney Reservoir	45° 27' 00" 109° 11' 06"	210	9/37-current	3,470	0.0	96.9	----
Willow Creek nr Boyd	45° 25' 20" 109° 13' 47"	53	6/37-current	1,720	0.0	----	----
Red Lodge Crk nr Boyd	45° 28' 09" 109° 05' 16"	234	4/32-12/32 5/34-12/36	1,400	0.0	----	----
Rock Creek at Joliet	45° 28' 31" 108° 59' 39"	539	10/45-9/53	1,930	18	253	----
Rock Creek @ Rockvale	45° 30' 59" 108° 51' 45"	569	10/20-12/21 3/22-9/22 4/32-3/33 2/34-9/40	2,310	0.0	133	----
Yellowstone River @ Billings	45° 47' 48" 108° 28' 12"	9200	4/04-12/05 8/28-current	66,100	430	6862	985

Figure 3. Schematic Diagram of Surface Waters in the Upper Yellowstone River Basin

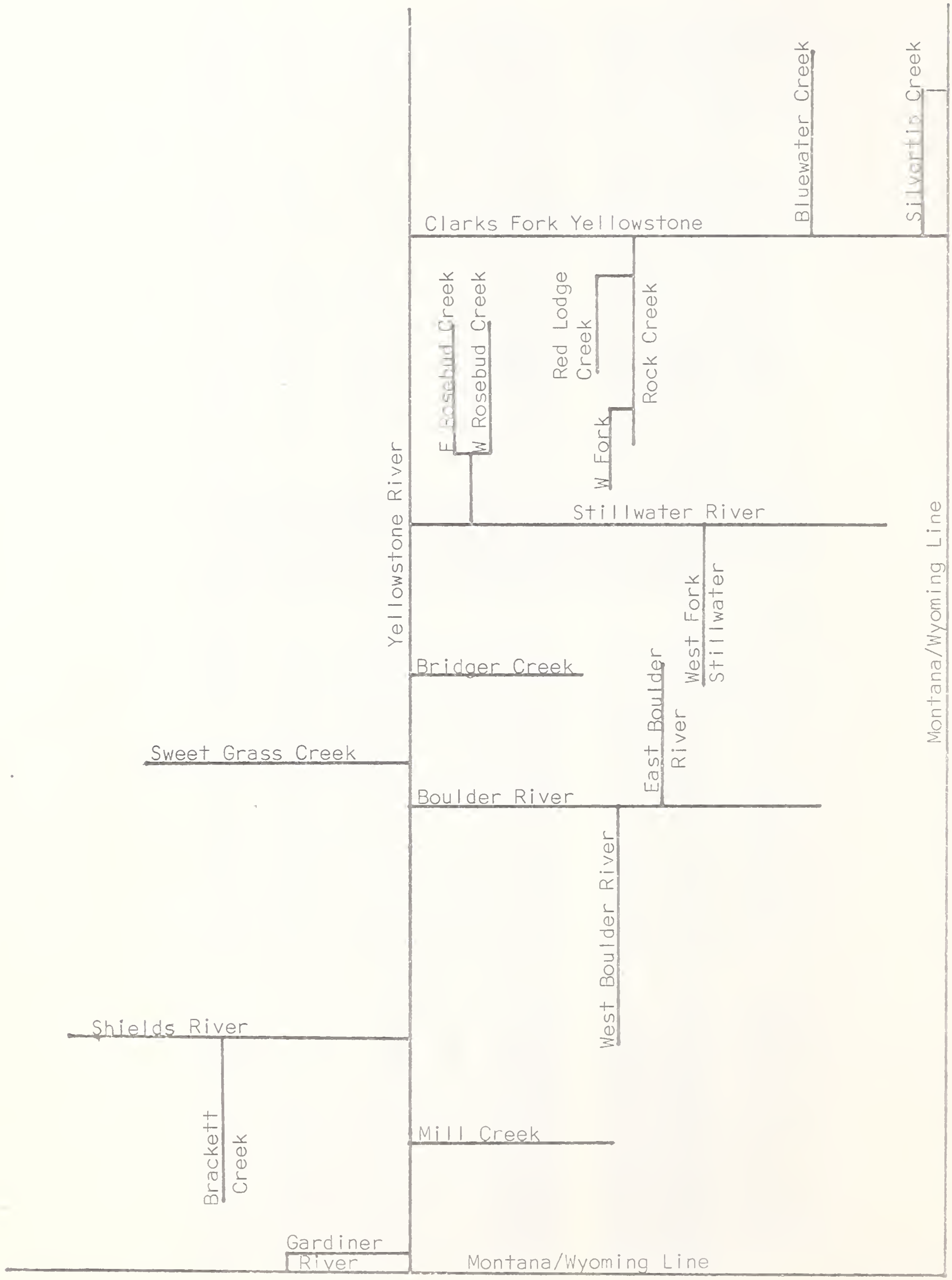
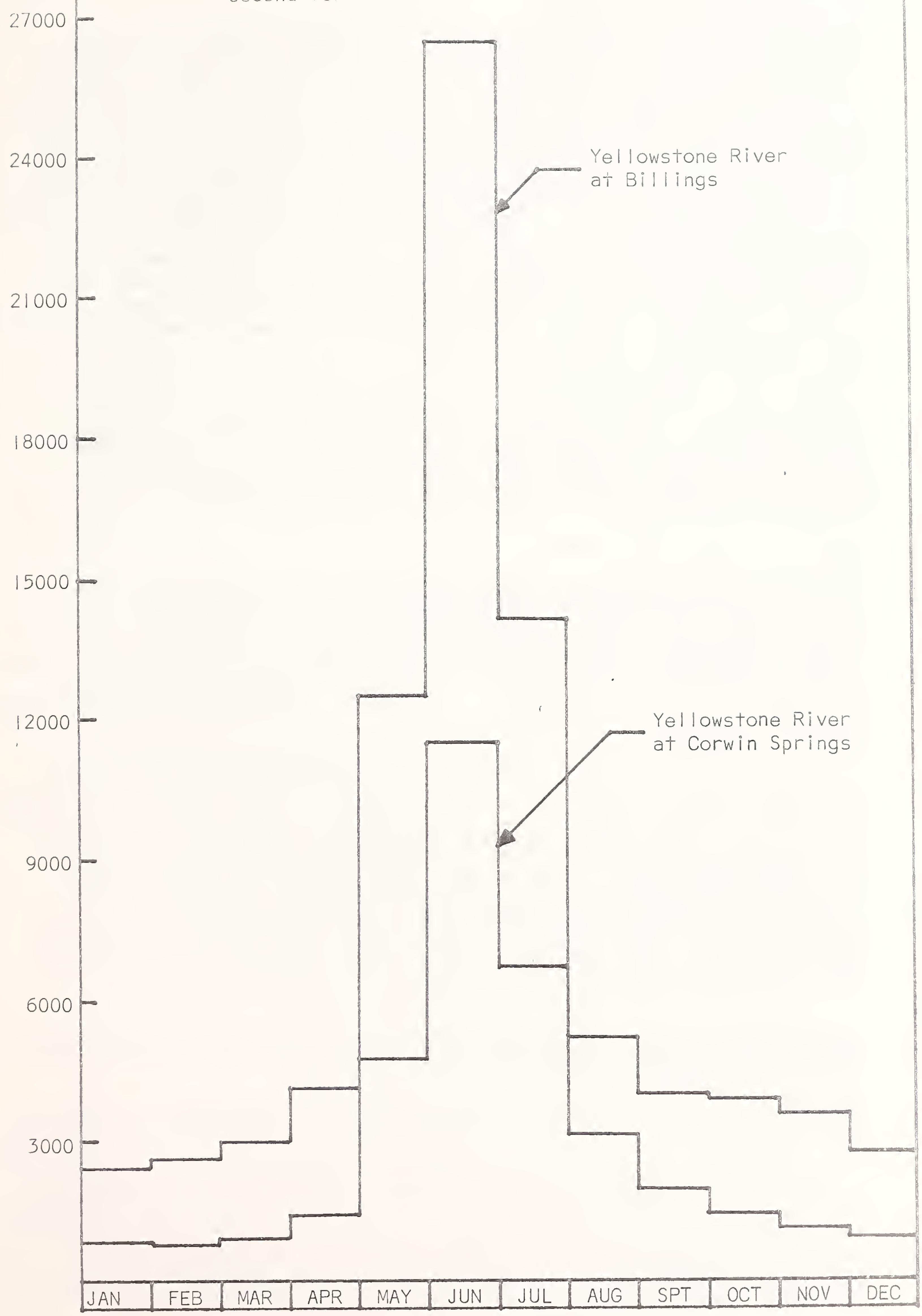


Figure 4. Yellowstone River at Billings and Corwin Springs. Average Mean Monthly Discharge in Cubic Feet per Second for the Period of Record.



Shields River Sub-basin

This sub-basin is approximately 875 square miles in size. It is located in the northeast section of the Upper Yellowstone River basin. This sub-basin drains the eastern slopes of the Bridger and the western slopes of the Crazy Mountains and thus comprises the valley between these mountains. The Shields River is the principal stream in the sub-basin. The headwaters of the Shields River are in the extreme northeast corner of the Upper Yellowstone River basin. The river flows generally southeasterly meeting the Yellowstone River just east of Livingston. Many of the tributaries to the Shields River are perennial, being fed by springs and melting snow from the Bridger and Crazy Mountains. Some of the principal tributaries are Smith, Potter, Flathead, Cottonwood, Brachett, and Rock Creeks (Plate 1, Figure 1). The U. S. Geological Survey has maintained stream gaging stations on Brachett Creek near Clyde Park and the Shields River near Clyde Park and Wilsall. The maximum discharge recorded on Brachett Creek was 1400 cfs and the minimum was 0.5 cfs. For the Shields River at Clyde Park the maximum has been 4500 cfs and the minimum has been 1.8 cfs (Ref. 1 and 6).

Boulder River Sub-basin

This sub-basin contains approximately 520 square miles of area. It drains one area of the Absaroka mountains. The Boulder River is the primary stream in the sub-basin. The river arises in the Absaroka mountains just south of the old abandoned mining community of Independence. It flows in a northerly and northeasterly direction joining the Yellowstone near Big Timber. Many of the tributaries to the Boulder River are perennial being fed by springs and melting snows in the Absaroka range. Some of the principal tributaries are Meat Rack Creek, West Boulder River, East Fork of Boulder River, and East Boulder River (Plate 1, Figure 1). The U. S. Geological Survey has maintained stream gaging stations on West Boulder River at Bruffey and McLeod. The maximum recorded discharge at the McLeod station was 1,990 cfs. The U. S. Geological Survey also maintains stations on the Boulder River near Contact and at Big Timber. The maximum recorded discharge at Big Timber has been 9840 cfs and the minimum 10 cfs (Ref. 1).

Yellowstone River Mainstem - Park Boundary to Bridger Creek and Sweet Grass Creek Sub-basins

These sub-basins are approximately 2890 square miles in size. The Yellowstone River is the major stream in this sub-basin. The river has its origins in the southeastern corner of Yellowstone National Park, a considerable distance south of Yellowstone Lake. The Yellowstone River enters the Upper Yellowstone River basin near Gardiner and flows generally northward until reaching Livingston where it turns and flows mostly easterly leaving the sub-basin below the confluence of Bridger Creek. Some of the principal tributaries to the

Yellowstone River have previously been discussed, namely the Shields and Boulder Rivers. Other principal tributaries are the Lamar and Gardiner Rivers and Mill and Sweet Grass Creeks. Although the Lamar River does not empty into the Yellowstone River in the Upper Yellowstone River basin, there is an area just north of Yellowstone National Park in this sub-basin which drains to the Lamar River. The Gardiner River has no drainage area in the Upper Yellowstone River basin, but enters the Yellowstone River immediately upon entering the Upper Yellowstone River basin (Plate 1, Figure 1). The U. S. Geological Survey has maintained stream gaging stations at Corwin Springs and near Livingston on the Yellowstone River, near Gardiner on the Gardiner River, near Pray on Mill Creek and above Melville on Sweet Grass Creek (Table 7). The maximum recorded discharge on Mill Creek near Pray was 2300 cfs and the minimum was 3.9 cfs (Ref. 6).

Stillwater River Sub-basin

This sub-basin contains approximately 1050 square miles of area. The Stillwater River is the principal stream in the sub-basin. The river has its headwaters in the mountainous area between the Absaroka and Beartooth ranges. It flows generally northeasterly meeting the Yellowstone near Columbus.

Some of the major tributaries to the Stillwater River are: West Fork of Stillwater River, East Rosebud and West Rosebud Creeks (Plate 1, Figure 1). The U. S. Geological Survey has maintained stream gaging stations on the Stillwater River near Nye and near Absarokee, on East Rosebud and West Rosebud Creeks near Roscoe, and Rosebud Creek near Absarokee (Table 1).

Clarks Fork Yellowstone River Sub-basin

This sub-basin is approximately 1584 square miles in size. The major stream is the Clarks Fork Yellowstone River. This river arises in the Beartooth Mountains, circles down around the southeastern slopes of the Beartooths in Wyoming, and then flows generally northward meeting the Yellowstone near Laurel. Some of the principal tributaries to the Clark Fork of the Yellowstone River are Silver Tip Creek, Bluewater Creek, West Fork Rock Creek, Rock Creek, and Red Lodge Creek. The U. S. Geological Survey has maintained gaging stations on the Clarks Fork Yellowstone River at Chance, at Fromberg, at Edgar, and at Silesia; on Silver Tip Creek near Belfry; on Bluewater Creek near Bridger and at Fromberg; on Rock Creek below Glacier Lake and near Red Lodge; on the West Fork of Rock Creek below Basin Creek and near Red Lodge; on Rock Creek at Joliet and at Rockvale; and on Red Lodge Creek above and below Cooney Reservoir and near Boyd (Table 7).

Yellowstone River Sub-basins - Bridger to Pryor Creek

This reach of the river is comprised of two sub-basins--43Q5 and part of 43Q west of Pryor Creek. These sub-basins contain approximately 1930 square miles. The Yellowstone River is the major stream in these sub-basins.

The river enters below the confluence of Bridger Creek and extends eastward to Laurel and then turns northeasterly leaving the Upper Yellowstone River basin prior to the confluence of Pryor Creek. Some of the principal tributaries to the Yellowstone River in these sub-basins have been previously described, namely, the Stillwater and Clarks Fork Yellowstone Rivers. A number of smaller streams also directly join the Yellowstone River through these sub-basins (e.g., Canyon Creek, Alkali Creek, Blue Creek, and Fivemile Creek); many of these are intermittent. The U. S. Geological Survey maintains a flow gaging station on the Yellowstone River at Billings (Table 7).

VIII. SURFACE WATER QUALITY

GENERAL FEATURES

A larger number of perennial streams occur in the Upper Yellowstone River basin than in the Middle or Lower Yellowstone River basins. Considerable water quality information for surface waters is available for the upper basin from previous studies. For example, the Montana Department of Fish and Game has conducted an extensive water quality and biological sampling program on several large tributaries to the Yellowstone River and on various smaller streams in relation to expected mining developments in south central Montana (Ref. 1 and 2). In addition, the U. S. Geological Survey (USGS) maintains several water quality and discharge monitoring sites in the basin on the Yellowstone River mainstem and on its larger tributary streams. The Montana Water Quality Bureau's (WQB) sampling program in the region was primarily designed to supplement available data and to supplement other data on file with the Bureau. Summarized in Table 8 are streams in the Upper Yellowstone River basin for which water quality data is available and the U. S. Geological Survey water quality monitoring and major flow measuring stations in and near the the basin.

Seven sub-basins are delineated in the Upper Yellowstone River basin (Ref. 3). These are:

(1) 43B ---- the Yellowstone River and tributaries from the Yellowstone National Park/Montana border to the confluence of Bridger Creek;

(2) 43BV --- Sweet Grass Creek and tributaries;

(3) 43A ---- the Shields River and tributaries;

(4) 43BJ --- the Boulder River and tributaries;

(5) 43C ---- the Stillwater River and tributaries;

(6) 43QJ --- the Yellowstone River and tributaries from the confluence of Bridger Creek to the confluence of the Clarks Fork Yellowstone River;

(7) 43D ---- the Clarks Fork Yellowstone River and tributaries;

(8) 43Q ---- the Yellowstone River and tributaries from the confluence of the Clarks Fork Yellowstone River to the confluence of Pryor Creek.

Quality of surface water in the larger sub-basins will be individually considered in this report. Due to limited availability of data, the discussion of the Yellowstone River sub-basin from Yellowstone Park to Bridger Creek was combined with the Sweet Grass Creek discussion.

Table 8

SUMMARY OF FLOW AND WATER QUALITY DATA AVAILABLE FOR THE UPPER YELLOWSTONE RIVER BASIN

Station Designation	Station Location*	Data Source**	Data Type: Flow	Data Type: Commons	Data Type: Metals	Data Type: Sed	Period of Collection (month/year)
Streams in the Lamar River Drainage:							
Miller Crk nr Cooke City	45 01 22 109 55 28	SRT	X	X	IC		8/71
Crk draining Horseshoe Basin	45 07 54 110 04 19	SRT	X	X	IC		8/71
Wounded Man Crk nr Horseshoe Basin	45 09 06 110 07 33	SRT	X	X	IC		8/71
Slough Crk nr Silver Gate	45 03 28 110 09 27	SRT	X	X	IC		8/71
Yellowstone River at lake outlet	44 34 03 110 22 48	USGS	(1)				12/22-Current
Yellowstone River at Corwin Springs	08S 08E 30 AC	USGS, WQBR	(1)	(1)	C		8/89-11/93; 9/10-Current
Yellowstone River nr Emigrant	05S 08E 27 CD	WQBR		X	IC		10/74
Yellowstone River nr Livingston	03S 09E 12 AAB	USGS, WQBR	(1)	(1)	C		5/97-12/05; 8/28-9/32; 10/37-Current
Yellowstone River below Livingston	01S 10E 26 CB	WQBR		X	IC		6/73; 10/74
Yellowstone River nr Springdale	01S 12E 15 CD	WQBR		X	IC		10/74
Yellowstone River nr Greycliff	01S 16E 08 AD	WQBR		X	IC		10/74
Yellowstone River Tributaries and Miscellaneous Sites:							
Gardiner River nr Gardiner	44 59 35 110 41 25	USGS, WQBR	(2)	X	IC		10/38-9/72
Bear Creek nr Jardine	09S 09E 08 DD	WQBR		X	IC		6/73
Cinnebar Creek nr Corwin Springs	08S 07E 24 CB	WQBR	X	X	IC	S	9/74
Cedar Creek nr Corwin Springs	08S 07E 13 BA	WQBR	X	X	IC		6/73
Tom Miner Creek nr Corwin Springs	07S 07E 30 AC	WQBR	X	X	IC	S	6/73-10/74
Rock Creek nr Corwin Springs	07S 07E 19 DB	WQBR	X	X	IC	S	9/74
Big Creek nr Corwin Springs	06S 07E 23 BD	WQBR	X	X	IC	S	6/73; 9/74
Emigrant Creek nr Emigrant	06S 08E 14 BA	WQBR	X	X	IC	S	6/74
Mill Creek near Pray	05S 09E 20 BD	WQBR	X	X	IC	S	9/74
Billman Creek at Livingston	02S 09E 26 AA	WQBR	X	X	IC	S	9/74
Big Timber Creek nr Big Timber	01N 14E 12 BD	WQBR	X	X	IC	S	10/74
Otter Creek nr Big Timber	01N 14E 07 AB	WQBR	X	X	IC	S	10/74
Carey Irrigation Project:					IC	S	
Pond	03N 15E 10 D	WQBR		X			8/74
Canal	03N 15E 10 D	WQBR		X	IC		8/74
Upper Deer Crk nr Greycliff	02S 14E 12	FG		X	C		5/72; 6/73; 10/73
Lower Deer Creek nr Greycliff	02S 15E 20	FG		X	C		5/72; 6/73; 10/73
Sweet Grass Crk abv Melville	05N 13E 27 A	USGS	(2)				8/13-12/24; 4/37-9/69

Table 8

- 2 -

Station Designation	Station Location*	Data Source**	Data Type				Period of Collection (month/year)
			Flow	Commons	Metals	Sed	
Bridger Creek near Reedpoint	01S 17E 19 BD	WQBR	X	X	IC		9/73
Smith Creek near Wilsall	05N 09E 24 D	WQBR	X	X	IC		6/73
Shields River near Wilsall	05N 09E 28 D	WQBR	X	X	IC		6/73
Shields River nr Clyde Park	02N 09E 33 AA	USGS, WQBR	(2)	X	IC	S	3/21-9/23; 4/29-12/32; 2/34-9/67
Shields River nr Livingston	01S 10E 26 BA	WQBR	X	X	C	S	9/73-10/74
Boulder River nr headwaters	07S 12E 17 C	SRT, WQBF	X	X	C		7/69; 7/71-8/71
Boulder River at Flemming Bridge	05S 12E 13	SRT, FG, WQBF	X	X	C		7/69; 6/71-9/72
Boulder River abv Clydehurst Ranch	45 27 29 110 11 54	SRT	X	X	IC		3/71-6/71
Boulder River nr Falls Crk Campground	04S 12E 15	SRT, FG	X	X	C		2/71-9/72; 11/72
Boulder River nr Contact	03S 12E 23 CC	USGS, SRT	(1)	(1)	C	X	5/10-9/16; 4/29-8/29; 10/50-9/69; 10/70-current
Boulder River nr Big Timber	01N 14E 14 CB	USGS, WQBR	(1)	X	IC		4/47-12/53; 3/55-current
Boulder River Tributaries:							
Basin Creek	07S 12E 17 C	WQBF	X	X	IC		7/69
Copper Creek	07S 12E 17 A	WQBF	X	X	IC		7/69
East Fork of Boulder River	06S 12E 33 B	WQBF	X	X	IC		7/69
Fourmile Creek	06S 12E 04 B	WQBF		X	IC		7/69
East Chippy Creek	04S 12E 01	FG		X	IC		2/72-11/72
Bobcat Creek	45 26 05 110 11 20	SRT	X	X	C		6/71-3/72
Blakely Creek	04S 12E 25	SRT, FG	X	X	C		6/71-11/72
Graham Creek	04S 12E 23	SRT, FG	X	X	C		6/71-11/72
Great Falls Creek	04S 12E 23	FG		X	IC		2/72-11/72
Falls Creek	04S 12E 23	SRT, FG	X	X	C		3/71-11/71; 2/72-11/72
Froze-to-Death Creek	45 29 53 110 13 27	SRT	X	X	C	S	3/71-11/71
East Boulder River nr headwaters	05S 13E 11	SRT, FG	X	X	C		5/73-10/73; 7/71-9/71
East Boulder River blw Canyon Crk	45 29 10 110 04 57	SRT	X	X	IC		8/71
East Boulder River @ Anderson Springs	03S 13E 29	SRT, FG, WQBF	X	X	C		2/71-9/72
East Boulder River @ Ewan Ranch	45 36 53 110 07 30	SRT	X	X	C		4/71-2/72
East Boulder River nr mouth	02S 13E 33	FG		X	IC		10/71-9/72; 11/72
East Boulder River Tributaries							
Forge Creek	05S 13E 02	FG		X	IC		5/73-10/73

Table 8

- 3 -

Station Designation	Station Location*	Data Source**	Data Type Flow	Commons	Metals	Sed	Period of Collection (month/year)
Unnamed Crk abv Amax Camp	45 25 06 110 04 56	SRT	X	X	I	S	7/71-9/71
Brownlee Crk at headwaters	45 26 24 110 07 22	SRT	X	X	I	S	7/71-9/71
Brownlee Crk near mouth	45 27 12 110 06 43	SRT	X	X	IC		8/71
Creek above Camp Lake	45 28 13 110 06 55	SRT	X	X	IC		7/71
Canyon Creek	45 29 04 110 05 00	SRT	X	X	IC		8/71
West Boulder River nr McLeod	03S 11E 25 D	SRT, WQBF	X	X	IC		7/69; 9/71
Stillwater River nr headwaters	09S 14E 04 D	SRT, WQBF	X	X	¯C		7/69-8/71
Stillwater R. nr Woodbine Campground	05S 15E 15 AB	SRT,AC,FG,WQBF	X	X	C		11/69-9/72
Stillwater R. abv West Fork	42 26 07 109 47 46	USGS	(3)			(4)	10/70-9/73
Stillwater R. nr Nye	04S 16E 31 CC	USGS,SRT,AC,WQBF	(1)	X	C		10/69-current
Stillwater R. nr Beehive	04S 16E 22 BB	USGS,SRT,AC,WQBF	X	(1)	C	X	12/69-current
Stillwater R. at Midnight Canyon Br.	04S 17E	WQBF		X	IC		12/69-3/71
Stillwater R. nr Absarokee	03S 19E 28 AB	USGS, WQBF	(1)	X	IC		7/10-9/14; 3/35-current
Stillwater R. nr Columbus	02S 20E 32 BB	WQBRF		X	C		10/74
Stillwater River Tributaries near Nye:							
Goose Crk abv Goose Lake	45 07 28 109 54 28	SRT	X	X	IC		7/71-8/71
Goose Crk at mouth	45 05 47 109 59 35	SRT	X	X	IC		8/71
Unnamed Crk SW of Beartooth Ranch	05S 15E 32 A	SRT, AC	X	X	C		3/71-11/71
Woodbine Creek	05S 15E 32	FG		X	IC		5/73-10/73
Verdigris Crk nr headwaters	45 22 41 109 53 32	SRT	X	X	C		6/71-8/71
Verdigris Crk nr mouth	05S 15E 28	SRT, FG, WQBF	X	X	C		11/69-10/73
Mountain View Crk, late outlet	45 23 12 109 54 00	SRT	X	X	C		6/71-11/71
Mountain View Crk nr mouth	05S 15E 21	SRT, FG, WQBF	X	X	C		6/71-11/72
Nye Crk nr headwaters	45 22 31 109 50 10	SRT	X	X	C		6/71-11/71
Nye Crk at mouth	05S 15E 15	SRT, FG, WQBF	X	X	IC		6/71-11/72
South Nye Creek	05S 15E 15	FG		X	IC		2/72-11/72
Silver Creek	05S 15E 15	FG, WQBF		X	IC		2/72-11/72
Little Rocky Crk nr Benbow Mine	45 21 46 109 47 52	SRT	X	X	C		6/71-8/71
Little Rocky Crk at campground	45 23 28 109 45 22	SRT	X	X	IC		6/71-8/71
Little Rocky Crk nr mouth	05S 16E 21	SRT, FG	X	X	C		3/71-11/72
West Fork of Stillwater River:							
abv Cresent Crk	05S 14E 30	SRT, AC, FG	X	X	C		12/69-8/71; 5/73-10/73
nr Forest Service boundary	05S 14E 12 A	SRT, AC, WQBF	X	X	C		12/69-11/71

Table 8

Station Designation	Station Location*	Data Source**	Data Type Flow	Commons	Metals	Sed	Period of Collection (month/year)
near Nye	04S 15E 26 D	USGS,SRT,AC,FG,WQBF	(3)	X	C	(4)	12/69-9/72
West Fork of Stillwater River Tributaries near Nye:							
Cresent Creek	05S 14E 29	SRT, FG	X	X	C		7/71-8/71; 5/73-10/73
Saderbalm (Sodderholm) Crk	45 22 44 109 59 35	SRT	X	X	IC		7/71-8/71
Cathedral Creek	05S 14E 14	SRT, FG	X	X	IC		8/71; 2/72-11/72
Initial Creek	05S 14E 14	SRT, FG	X	X	C		6/71-11/72
Iron Crk nr headwaters	45 24 48 110 02 46	SRT	X	X	I	S	7/71-9/71
Iron Crk at mouth	05S 14E 12	SRT, FG	X	X	IC		6/71-8/71; 2/72-11/72
Picket Pin Creek	05S 14E 03	SRT, FG	X	X	IC		7/71-11/72
Castle Creek	45 27 17 109 50 48	USGS	(3)			(4)	10/72-9/73
West Rosebud Crk nr Pine Grove	06S 17E 28	SRT, FG, WQBF	X	X	C		11/69; 8/70; 2/71-11/72
West Rosebud Crk blw Pine Grove	06S 17E 02	SRT, FG, WQBF	X	X	C		8/70; 4/71-11/72
West Rosebud Crk nr Roscoe	07S 16E 10 B	USGS	(1)				9/65-current
West Fishtail Creek	05S 17E 19	SRT, FG	X	X	C		7/71-11/72
East Fishtail Creek	05S 17E 19	FG		X	IC		2/72-11/72
East Rosebud Creek abv lake	07S 17E 28 DA	SRT, WQBF	X	X	IC		11/69; 7/71-9/71
East Rosebud Creek nr Jimmie Joe Cmpgr	07S 17E 11	SRT, FG, WQBF	X	X	C		11/69; 8/70; 4/71-11/72
East Rosebud Creek nr Down Br.	06S 18E 16	SRT, FG, WQBF	X	X	C		8/70; 7/71-11/72
Morris Creek	06S 18E 08	FG, WQBF		X	IC		8/70; 2/72-11/72
Rosebud Creek nr Absarokee	04S 18E 13AD	USGS	(2)				4/35-9/69
Clarks Fork Yellowstone River:							
nr Belfry (Chance)	09S 22E 31 B	USGS, SRT, WQBF	(1)	(1)	IC	S	7/21-current
nr Belfry	08S 22E	WQBF		X	I	S	7/69-9/69
abv Silver Tip Creek	07S 22E	WQBF		X		S	7/69-9/69
nr Bridger	06S 23E	WQBF		X		S	7/69-9/69
nr Fromberg	05S 23E	WQBF		X		S	7/69-9/69
nr Edgar	04S 23E 23 CC	USGS, WQBF	(3)	X	I	(4)	7/69-9/69; 7/72-6/73
nr Silesia	04S 23E 01 CB	USGS	(1)				10/69-current
nr Laurel	02S 24E 28CC	USGS, SRT, WQBRF	(3)	(1)	C	S	2/67-9/68; 7/69-9/73; 9/74-11/74
Clarks Fork Yellowstone River Tributaries:							
Big Sand Coulee nr MT/WYO line	09S 22E 32DB	USGS, WQBF	(3)	X		(4)	7/69-9/69; 5/73-9/73
Fisher Creek at Clarks Fork headwaters	---	SRT	X	X	IC		8/71

Table 8

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Station Designation	Station Location*	Data Source**	Data Type				Period of Collection (month/year)
			Flow	Commons	Metal	Sed	
Big Sand Coulee nr Chance	09S 22E 04 D	WQBF		X	I	S	7/69-9/69
Bear Creek nr Belfry	08S 22E 15 AA	WQBF		X	I	S	7/69-9/69
Silver Tip Creek nr Belfry	08S 22E 12 AB	USGS, SRT, WQBF	(1)	(1)	IC	(1)	10/67-current
Cottonwood Creek nr Bridger	07S 23E 08 DB	WQBF		X	I	S	7/69-9/69
North Fork Bluewater Crk nr Bridger	06S 24E 15 DA	USGS	(3)			(4)	3/60-9/62; 10/63-9/70
Bluewater Crk nr Bridger	06S 24E 09 AA	USGS	(2)			(4)	3/60-9/70
Bluewater Crk at Sanford Ranch	06S 24E 06 DC	USGS	(3)			(4)	3/60-9/62; 10/63-9/70
Bluewater Crk nr Fromberg	05S 23E 27 CD	USGS, WQBF	(2)	X		(4)	3/60-9/70
West Fork of Rock Creek:							
near headwaters	08S 19E 04 AC	SRT, WQBF	X	X	IC		11/69; 7/71-9/71
near mouth	08S 20E 06 BC	SRT, WQBF	X	X	I		11/69; 9/71
Rock Creek blw Glacier Lake	09S 18E 32	USGS	(2)		IC		9/60-9/64
Rock Creek near headwaters	09S 19E 08 DD	SRT, WQBF	X	X	IC		11/69; 9/71
Rock Creek near Red Lodge	08S 20E 20 AA	USGS, WQBF	(1)	X	I		5/32-12/32; 5/34-current
Red Lodge Crk abv Cooney Reservoir	04S 20E 33 CC	USGS	(1)				5/37-current
Willow Creek nr Boyd	05S 20E 02 DD	USGS	(1)				6/37-current
Red Lodge Creek blw Cooney Reservoir	04S 21E 31 A	USGS	(1)				9/37-current
Rock Creek nr Rockvale	04S 23E 03 AD	WQBRF	X	X	IC	S	7/69-9/69; 9/74
Spring Creek nr Laurel	02S 24E 24 BC	WQBR	X	X	IC	S	9/74
Yellowstone River nr Columbus	03S 21E 05 DA	WQBR		X	IC		10/74
Yellowstone River abv Clarks Fork	02S 24E 15 CC	WQBR		X	IC	S	9/74-11/74
Yellowstone River nr Laurel	02S 24E 28 CC	USGS, SRT, WQBRF	X	(1)	C	S	2/67-9/68; 7/69-9/73; 9/74-10/74
Yellowstone River at Billings	01N 26E 34 AA	USGS, WQBRF	(1)	(1)	C	X	5/04-12/05; 8/28-current
Yellowstone River at Huntley	02N 27E 24 D	USGS, WQBRF		(1)	IC	S	10/50-9/52; 2/67-9/68; 7/72-9/73
Yellowstone River Tributaries and Miscellaneous Sites:							
Pond near Wheat Basin	02N 21E 24	WQBR		X	IC		10/74
Pond north of Columbus	01N 21E 07 CA	WQBR		X	IC		10/74
Duck Creek nr Laurel	02S 25E 04 DB	WQBR	X	X	IC	S	9/74
Canyon Creek near Billings	01S 25E 26 BD	WQBR	X	X	IC	S	10/74

Table 8

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* Location given as Township-Range-Section where available; alternately given as latitude-longitude: degrees-minutes-seconds.

** Data obtained from the following sources:

(a) from recent collections (post-1972) by the State Water Quality Bureau (Montana Department of Health and Environmental Sciences) (WQBR);
(b) on file with the Water Quality Bureau (collected pre-1972) (WQBF);
(c) from United States Geological Survey publications--*Water Resources Data for Montana. Parts 1 and 2. Surface Water Records, Water Quality Records*, October, 1963 to September, 1973 (USGS);
(d) from the Montana Department of Fish and Game, job progress reports--FW-2-R-1 and FW-2-R-2 (FG);
(e) from the Anaconda Company, Environmental Engineering Department (AC);
(f) and from Storet (SRT).

(1) Permanent water quality and/or flow monitoring stations maintained by the United States Geological Survey and in operation as of September, 1973.
(2) Permanent water quality and/or flow monitoring stations maintained by the United States Geological Survey but now discontinued.
(3) Partial water quality and/or flow records available for these sites from the United States Geological Survey.
(4) United States Geological Survey records for these sites for discharge, temperature and sediment only.
(5) C --Several metal parameters analyzed for several samples.
IC--Several metal parameters analyzed for a few samples.
I --An incomplete metals analysis.
S --Some sediment data available but only for a few samples.

Similarly, the two Yellowstone River sub-basins downstream from Bridger Creek were combined. All data reported for 1974 were obtained by the WQB. Data were selected from USGS records to illustrate the flow-related variations in water quality; water quality data at the spring runoff-high flow period, at low flow-summer and winter periods (warm weather and cold weather low flows), and at intermediate flow regimes between these extremes (upsurge and down-surge periods) were emphasized in this report. The USGS information for water years 1966 to 1973 (Ref. 4) were used in this report.

Suitability of waters in the Upper Yellowstone River basin are dependent upon an intended water use. Quality of water necessary for agricultural or industrial use is different from that required for recreational purposes or for human consumption. As a result, water quality standards and criteria have been developed to evaluate the suitability for various uses. Montana Water Quality Standards (Appendix B) and criteria and standards available from four other sources were used in evaluating waters of the Upper Yellowstone Basin. These are: (1) standards established by the Public Health Service (PHS) for drinking water (Ref. 5); (2) the National Technical Advisory Board for surface water supplies (Ref. 6); (3) the Environmental Protection Agency (EPA) for public water supplies (Ref. 7); and (4) the California State Water Quality Control Board (CWQCB) for livestock (Ref. 8). These criteria and standards are summarized in Table 9. In addition, water quality recommendations presented by the EPA for freshwater aquatic life and for agricultural uses (Ref. 7) were also considered in evaluations of surface waters of the Upper Yellowstone River basin.

Field procedures and methods of analyses used by the WQB were in accordance with standard techniques (Ref. 9-14). Trace metals data obtained by the WQB can be termed as "total recoverable" metals and were determined from unfiltered samples, acidified with 5 ml of concentrated nitric acid (Ref. 9). Common constituents and metals are designated by their chemical symbols in the following tables with concentrations given in milligrams per liter (mg/l). The following abbreviations and concentration units are also used:

Flow -- cubic feet per second (cfs) (an "E" denotes an estimated flow)
Temp -- temperature in degress centrigrade
DO ---- dissolved oxygen in mg/l
BOD --- bio-chemical oxygen demand in mg/l
FC ---- fecal coliforms in colony counts per 100 ml of sample
Turb -- turbidity in Jackson Turbidity Units (JTU)
SC ---- specific conductance in micromhos per cm @ 25°C
TA ---- total alkalinity as mg/l of $CaCO_3$
TH ---- total hardness as mg/l of $CaCO_3$
DS ---- generally a calculated dissolved solid in mg/l (i.e., a sum of constituents)
TSS --- total suspended sediment in mg/l
SAR --- sodium adsorption ratio (Ref. 15, pp. 228-229)

TABLE 9

Selected water quality criteria and standards as compiled by four sources: Public Health Service (PHS), "Drinking Water Standards"; Environmental Protection Agency (EPA), "Public Water Supplies"; National Technical Advisory Board (NTAB), "Surface Water Criteria for Public Supplies"; and California State Water Quality Control Board (CWQCB), "Water Quality for Livestock." Concentrations are given as milligrams per liter, temperature in degrees centigrade, turbidity in JTU, and bacteria as number per 100 ml (va -- virtually absent; sat -- near saturation; vary -- variable, dependent on sampling technique or temperature; ap -- approximately).

	PHS	EPA	NTAB		CWQCB	
Constituent	Standard	Recommendation	Permissible Criteria	Desirable Criteria	Threshold Concentration	Limiting Concentration
Temperature			24			
pH		5-9	6-8.5		6-8.5	5.6-9.0
Dissolved Oxygen			3	sat		
Fecal coliforms	vary	2000	2000	20		
Turbidity	5		75	va		
Dissolved solids	500		500	200	2500	5000
Nitrate	45	ap 60	ap 60	va		
Bicarbonate					500	500
Calcium					500	1000
Chloride	250	250	250	25	1500	3000
Fluoride	vary	vary	vary	vary	1.0	6.0
Magnesium					250	500
Sodium					1000	2000
Sulfate	250	250	250	50	500	1000
Arsenic	0.01	0.1	0.05	none	1.0	
Boron			1.0	va		
Cadmium	0.01	0.01	0.01	none	5	
Chromium	0.05	0.05	0.05	none		
Copper	1.0	1.0	1.0	va		
Iron	0.3	0.3	0.3	va		
Lead	0.05	0.05	0.05	none		
Manganese	0.05	0.05	0.05	none		
Mercury		0.002				
Zinc	5.0	5.0	5.0	va		

In a few cases, dissolved solids (DS) were determined as mg/l of filterable residue at 180°C. An asterisk by the date for a set of water quality data denotes a composite sample analysis by the U. S. Geological Survey for all or some of the parameters listed. All nitrate (NO_3) and phosphate (PO_4) concentrations are presented as the radical weight rather than NO_3-N or PO_4-P. The "T" in the PO_4 column denotes a total phosphate concentration as ortho-PO_4 for those samples where orthosphosphate values were not determined. An asterisk in the sodium (Na) column denotes an estimate of "Na + K" concentrations in mg/l. Data from the Montana Department of Fish and Game (Ref. 1 and 2) were obtained as statistical summaries of two to sixteen samples (minimum, maximum, and mean values of each parameter at each stream site). These samples were collected during the period of October 1971 to October 1973. The major deficiency in the Fish and Game's statistical summary of water quality information and that from certain other non-USGS sources is the lack of accompanying discharge data.

Yellowstone River Sub-basin -- Yellowstone National Park/Montana boundary to the confluence of Bridger Creek, and the Sweet Grass Creek Sub-basin

The reach of the Yellowstone River from Gardiner to below Greycliff including the Paradise Valley is located within this sub-basin. Both the Shields River and Sweet Grass Creek draining the Crazy Mountains northeast of Livingston and the Boulder River with its headwaters in the Absaroka Range southeast of Livingston enter the Yellowstone at points through this sub-basin. The Yellowstone River is the major stream in the region; however, numerous relatively small, but perennial and direct tributaries of the Yellowstone River similar to Sweet Grass Creek enter the river in this reach. The flow in these creeks can approach and exceed 100 cfs at times especially during the period of spring runoff from mountain snowmelt in the area. The flow regime of Sweet Grass Creek probably typifies that of most small streams in the sub-basin with winter flows at less than 50 cfs increasing to values approaching and exceeding 300 cfs during late May, June, and early July. Of the 2.2-fold increase in the mean yearly discharge of the Yellowstone River between Corwin Springs and Billings, about 21% of this is attributable to the inputs of such small tributaries plus groundwater.

In addition to the direct tributaries of the Yellowstone River in the sub-basin, the headwaters of several small streams that drain south to the Lamar River are located in the extreme southern portion of the region. The Lamar River is also a tributary of the Yellowstone River and joins the Yellowstone near Tower Falls in Yellowstone National Park. Some water quality data is available for these small streams from STORET (Table 10) (STORET is a national water quality data bank).

At the present time, the USGS has water quality and continual discharge monitoring sites only on the Yellowstone River mainstem in the sub-basin -- at Corwin Springs (water quality collections discontinued in September 1973) and near Livingston. In addition, past flow records are available for the Gardiner River near Mammoth (near Gardiner) and for Sweet Grass

Creek above Melville; both of these sites are no longer operative. Water quality data selected from USGS records for the sub-basin and supplemental data from WQB collections are presented in Table 10.

The Yellowstone River in this sub-basin has relatively low concentrations of dissolved solids with a calcium-sodium-bicarbonate-type of water. Sulfate is a secondary anion with concentrations generally slightly greater than those of calcium and sodium. Potassium, magnesium, and chloride are minor constituents of this water. Dissolved solid concentrations in this reach of the Yellowstone River are consistently less than 220 mg/l and were found to be commonly highest at low flow periods and at downstream sites. Calcium and bicarbonate primarily account for the downstream increase in dissolved solids; the concentrations of these parameters tend to increase downstream through this reach of the Yellowstone River while sodium and sulfate values tend to remain constant. Thus, the river becomes more predominantly calcium-bicarbonate in nature from Gardiner to the confluence of Bridger Creek. The non-basin and intra-basin tributary waters that enter the Yellowstone through this reach are markedly calcium bicarbonate in composition.

Fluoride was also found to be a minor constituent of the river in this sub-basin, but concentrations were consistently higher than those in most of the tributary streams and higher than concentrations in water from downstream sites on the river. This is probably a reflection of thermal discharges into the upstream reaches of the river in Yellowstone National Park (e.g., from geyser activity). High fluoride concentrations are typical of thermal discharges in the Park. For example, the Firehole and Madison Rivers receiving thermal waters from the Old Faithful geyser basins had concentrations of fluoride commonly greater than 5 mg/l (Ref. 16).

In contrast to the Yellowstone River mainstem, water in small streams of the sub-basin (including the Sweet Grass Creek sub-basin and Lamar drainage) are calcium-bicarbonate types with magnesium, sodium, and sulfate present as minor constituents. Potassium and fluoride are insignificant components of the streams. Dissolved solids and specific electrical conductances vary considerably between creeks of the sub-basin, ranging from values less than those of the mainstem to values markedly higher. Along with the Yellowstone River mainstem, creeks in the sub-basin are non-saline (less than 1,000 ppm dissolved solids) and are generally soft to moderately hard (Ref. 15). Quality of surface waters in the sub-basin is generally good. Based on limited data, suspended sediment in the Yellowstone River and tributary creeks does not significantly detract from this good quality. Turbidities were generally less than 20 JTU with suspended sediment concentrations commonly lower than 6.0 mg/l; higher values occurred primarily during high flow periods.

Temperatures vary with season in this reach of the Yellowstone River and range from 0.0°C in the winter to near 18.0°C during the summer. This range is typical of cold water, trout habitats and is also observed in smaller streams in the region. Dissolved oxygen concentrations in

Table 10

Typical Chemical Analyses of Water in the Yellowstone River Sub-basin--
Yellowstone National Park/Montana boundary to the Confluence of Bridger Creek (43B) and in the Sweet Grass Creek Sub-basin (43BV)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Lamar River Drainage																																		
Miller Creek	SRT	8/26/71	8.5	2.5	8.03	152	115.1	---	---	---	---	---	24.0	2.6	71	0.8	0.6	0.0	66	54	21.0	0.1	0.0	0.0	0.05T	0.0	0.0	---	0.01	---	0.002	---	0.005	0.01
Cr. draining Horseshoe Basin	SRT	8/10/71	---	5.0	7.31	70	47.1	---	---	---	---	---	7.8	1.6	26	1.6	1.2	0.1	23	19	11.6	0.3	0.0	0.0	0.05T	0.005	0.08	---	0.01	---	0.002	---	0.005	0.01
Wounded Man Creek	SRT	8/10/71	---	10.0	7.02	40	25.2	---	---	---	---	---	3.1	1.4	13	1.1	0.8	0.1	14	12	4.4	0.4	0.0	0.0	0.05T	<.001	0.0	0.01	0.01	---	0.002	---	0.005	0.01
Slough Creek	SRT	8/10/71	---	89.6	7.83	133	106.4	---	---	---	---	---	17.9	4.3	62	2.4	1.7	0.1	73	60	6.4	0.7	0.0	0.0	---	0.0	0.0	---	0.01	---	0.002	---	0.005	---
Yellowstone River Mainstem																																		
@ Corwin Springs	WQB	10/1/74	---	2100	7.60	226	151	---	<1	9.5	---	---	14.3	6.0	60	19	---	1.1	70	58	30	10.9	---	0.49	0.24	0.12	0.C3	<.01	<.01	<.01	0.031	0.31	<.01	<.001
@ Corwin Springs	USGS	2/20/70*	0.5	902	8.1	300	188	3.0	---	11.4	3.0	---	---	---	73	27	5.8	---	---	75	38	---	1.2	1.77	0.09	0.054	0.023	0.015	0.020	0.0	0.024	0.510	0.0	0.0
@ Corwin Springs	USGS	6/26/70*	11.0	16700	7.7	93	60	50	---	9.8	0.6	---	---	---	28	6.6	1.8	---	---	26	7.5	---	0.4	0.44	0.12	0.123	0.013	0.050	0.013	0.0	0.011	0.106	0.0	0.0
@ Corwin Springs	USGS	7/24/70	16.5	6400	7.5	130	90	---	---	8.1	0.8	---	8.4	3.0	33	11	---	---	---	---	13	4.9	0.3	0.13	0.46T	---	0.0	0.009	0.010	0.0	0.012	0.16	0.0	0.0
@ Corwin Springs	USGS	10/23/70	5.5	1570	8.3	220	149	---	---	11.0	1.0	88	15	5.0	58	20	---	---	---	---	29	10	0.9	1.77	0.18T	---	0.01	0.010	0.0	0.0	0.020	0.35	0.0	0.0
@ Corwin Springs	USGS	4/27/71	7.0	1510	8.4	255	190	---	---	12.2	1.1	7	20	6.4	76	15	---	---	---	---	32	12	0.7	0.44	0.18T	---	0.02	0.020	0.020	0.0	0.0	0.39	0.0	0.0
@ Corwin Springs	USGS	7/26/71	16.0	7990	7.5	130	84	---	---	8.6	1.0	24	9.2	3.0	35	10	---	---	---	---	60	5.4	0.5	8.42	0.18T	---	0.76	0.0	0.001	0.0	0.005	0.17	0.0	0.0
@ Corwin Springs	USGS	1/25/72	0.0	854	7.7	300	218	---	---	12.0	1.6	42	23	7.1	87	29	---	1.3	---	---	48	18	1.0	1.51	0.34	---	0.04	0.008	0.004	0.002	0.030	0.63	0.0	0.0
@ Corwin Springs	USGS	4/24/72	9.0	1560	8.4	240	182	---	---	11.4	1.1	6	17	5.8	66	20	---	1.1	---	---	32	12	0.8	0.58	0.21	---	0.02	0.010	0.001	0.005	0.010	0.38	0.0	0.001
@ Corwin Springs	USGS	7/25/72	16.0	5810	7.5	150	98	---	---	8.6	1.2	30	8.7	3.1	34	11	---	0.8	---	42	16	5.0	0.5	---	---	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	9/26/72	9.0	2280	7.3	220	156	---	---	11.0	1.6	4	15	5.3	59	19	---	1.1	---	49	31	9.2	0.8	---	---	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	10/26/72	5.5	2310	7.0	190	128	---	---	10.8	1.6	61	13	4.6	51	17	---	1.0	---	47	25	8.4	0.8	0.22	0.03	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	1/23/73	0.0	1120	7.0	290	218	---	---	13.0	0.6	0	19	6.0	72	22	---	1.1	---	69	39	13	1.0	0.80	0.03	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	5/23/73	7.0	8700	7.3	120	85	---	---	10.6	1.5	3	13	2.8	44	6.9	---	0.5	---	20	11	2.1	0.3	---	---	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	6/26/73	10.5	8390	6.4	95	78	---	---	9.6	0.8	3	7.9	2.7	31	8.8	---	0.7	---	17	9.4	3.3	0.4	---	---	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	7/25/73	17.0	3610	6.7	155	112	---	---	9.2	0.8	2	11	3.9	44	14	---	0.9	---	48	18	7.0	0.6	0.17	0.06	---	---	---	---	---	---	---	---	---
@ Corwin Springs	USGS	8/28/73	8.0	1920	6.8	255	164	---	---	8.4	1.6	25	15	4.9	58	21	---	1.2	---	62	34	11	0.8	0.35	0.0	---	---	---	---	---	---	---	---	---
nr Emigrant	WQB	10/1/74	---	1900E	7.80	266	192	---	<1	9.9	---	---	28	4.8	91	15	---	0.7	104	85	32	7.0	---	0.44	0.37	0.049	0.04	<.01	<.01	<.01	0.025	0.12	<.01	<.001
nr Livingston	WQB	6/5/73	13.0	7290	8.10	144	111	---	---	9.5	---	---	15.0	4.4	55	10	---	0.6	66	54	12.0	3.0	0.3	0.32	---	0.25	---	1.1	<.01	<.01	<.01	---	---	<.01
nr Livingston	WQB	10/1/74	---	2240	7.79	247	189	---	<1	10.0	---	---	23	6.2	84	20	---	0.9	101	83	30	7.2	---	0.20	0.15	0.23	0.26	<.01	<.01	<.01	0.015	0.12	<.01	<.001
nr Livingston	USGS	1/22/70	3.5	1360	7.3	307	186	---	---	---	---	---	24	7.9	92	21	5.8	1.0	110	---	35	9.4	0.8	0.53	---	0.04	---	---	---	---	---	0.42	---	---
nr Livingston	USGS	4/24/70	6.5	1360	7.7	298	190	---	---	---	---	---	23	7.6	89	24	6.4	1.1	112	---	39	9.1	0.9	0.04	---	0.33	---	---	---	---	---	0.42	---	---
nr Livingston	USGS	6/23/70*	---	18700	7.5	100	70	---	---	---	---	---	9.6	3.0	36	5.4	1.8	0.4	49	---	8.0	2.0	0.2	0.18	---	---	---	---	---	---	---	0.05	---	---
nr Livingston	USGS	7/23/70	14.0	7900	7.7	151	100	---	---	---	---	---	13	4.4	51	10	2.8	0.6	63	---	16	5.1	0.6	0.0	---	0.05	---	---	---	---	---	0.07	---	---
nr Livingston	USGS	1/26/71	---	1680	7.6	243	160	---	---	---	---	---	21	5.9	77	19	5.0	0.9	102	---	24	9.4	0.9	0.0	0.10	0.16	0.0	---	---	---	---	0.38	---	---
nr Livingston	USGS	4/26/71	8.0	2150	8.4	247	166	---	---	---	---	---	23	6.6	85	18	5.6	0.9	95	---	26	8.5	0.7	0.44	0.06	0.05	0.11	---	---	---	---	0.20	---	---
nr Livingston	USGS	6/20/71*	---	22800	7.0	95	70	---	---	---	---	---	9.2	2.7	34	5.4	1.5	0.4	52	---	7.0	1.9	0.6	0.09	0.09	0.03	---	---	---	---	---	---	---	---
nr Livingston	USGS	7/27/71	17.0	9060	7.7	143	101	---	---	---	---	---	11	4.0	44	12	2.1	0.8	71	---	15	4.9	0.6	0.22	0.15	0.02	0.0	---	---	---	---	0.14	---	---
nr Livingston	USGS	9/16/71*	---	3320	7.6	213	145	---	---	---	---	---	19	6.3	73	14	3.1	0.7	94	---	29	7.1	0.6	0.04	0.03	0.0	---	---	---	---	---	---	---	---
nr Livingston	USGS	1/25/72	0.0	1250	7.7	327	216	---	---	---	---	---	28	8.9	110	21	5.6	0.9	131	---	41	12	0.8	1.73	---	0.12	0.01	---	---	---	---	0.41	---	---
nr Livingston	USGS	6/22/72*	---	17600	6.4	108	74	---	---	---	---	---	9.6	2.9	36	7.5	1.6	0.5	49	---	10	3.0	0.6	0.04	0.03	0.02	---	---	---	---	---	---	---	---
nr Livingston	USGS	7/25/72	15.5	6350	7.4	151	100	---	---	---	---	---	13	4.3	50	11	2.4	0.7	65	---	15	4.0	0.5	0.44	0.03	0.03	0.0	---	---	---	---	0.16	---	---
nr Livingston	USGS	9/16/72*	---	3440	7.9	208	131	---	---	---	---	---	18	5.6	68	13	3.3	0.7	86	---	22	6.5	0.6	0.0	0.0	0.02	---	---	---	---	---	---	---	---
nr Livingston	USGS	1/24/73	0.5	1560	7.7	245	193	---	---	---	---	---	25	7.5	93	20	4.7	0.9	106	---	44	11	1.0	0.93	0.09	0.05	0.0	---	---	---	---	0.38	---	---
nr Livingston	USGS	4/26/73	9.5	1510	8.1	281	182	---	---	---	---	---	23	7.4	88	21	5.0	1.0	110	---	36	10	0.8	0.35	0.06	0.05	0.02	---	---	---	---	0.38	---	---
nr Livingston	USGS	6/16/73*	---	11300	8.2	120	81	---	---	---	---	---	12	3.2	43	6.3	1.7	0.4	60	---	9.5	2.7	0.2	0.0	0.06	0.01	---	---	---	---	---	---	---	---
nr Livingston	USGS	7/25/73	17.5	4390	8.0	183	119	---	---	---	---	---	15	5.1	58	13	2.8	0.7	79	---	18	6.4	0.7	0.13	0.06	0.07	0.02	---	---	---	---	0.17	---	---
nr Livingston	USGS	8/26/73*	---	2640	7.7	226	151	---	---	---	---	---	20	6.2	75	16	3.7	0.8	109	---	23	8.0	0.6	0.0	0.15	0.02	---	---	---	---	---	---	---	---
below Livingston	WQB	6/5/73	13.0	7700E	8.10	141	113	---	---	8.5	---	---	14.0	4.4	53	11	---	0.7	65	53	13.0	5.0	0.3	0.34	---	0.36	---	0.58	0.02	0.04	<.01	---	---	<.01
below Livingstoo	WQB	10/1/74	---	2400E	7.80	259	187	---	<1	11.9	---	---	22	8.2	88	16	---	0.7	104	85	29	7.9	---	0.13	0.21	0.24	0.09	<.01	<.01	<.01	0.014	0.29	<.01	<.001
nr Springdale	WQB	10/1/74	---	2400E	8.03	278	207	---	<1	11.2	---	---	27	7.3	98	16	---	0.7	115	94	34	6.9	---	0.03	0.06	0.31	0.02	<.01	<.01	<.01	0.015	0.11	<.01	<.001
nr Greycliff	WQB	10/1/74	---	2700E	8.21	292	217	---	<1	10.6	---	---	27	9.6	106	17	---	0.7	105	105	29	6.5	---	0.04	0.06	0.15	0.07	0.01	0.01	<.01	0.021	0.27	<.01	<.001
Yellowstone River Tributaries and Miscellaneous																																		
Cardiner River	WQB	6/18/73	10.0	120	7.90	308	235	---	---	9.8	2.3	2	35	8.8	123	17	---	0.7	113	93	50	11.1	0.75	0.07	0.09	0.22	---	0.07	0.03	<.01	0.03	---	---	<.01
Bear Creek	WQB	6/5/73	---	25E	7.10	42	40	---	---	9.4	---	---	4.6	1.2	16	5.2	---	0.6	27	22	2.0	0.0	0.04	0.11	---	0.06	---	0.20	0.01	0.06	0.01	---	---	<.01
Cinnabar Creek	WQB	9/11/74	7.0	6.6	8.25	319	255	---	3.5	9.9	1.9	233	36	13.0	144	9.2	---	0.3	159	130	35	2.0	---	0.05	0.21	0.12	0.20	0.01	<.01	<.01	0.001	---	<.01	<.001
Cedar Creek	WQB	6/19/73	6.0	25.0	8.10	117	98	2	---	10.8	2.7	2	12.0	5.0	50	5.2	---	0.3	68	56	7.0	0.4	0.05	0.11	0.08	0.32	---	0.08	0.04	0.05	<.01	---	---	0.01
Tom Miner Creek	WQB	6/18/73	7.5	75.0	8.00	119	101	18	---	7.6	1.5	78	13.0	4.0	49	7.5	---	0.5	70	57	5.5	0.9	0.08	0.12	0.27	0.62	---	0.06	0.02	0.70	<.01	---	---	<.01
Tom Miner Creek	WQB	9/11/74	5.5	32.6	8.21	172	135	---	3.0	10.8	2.8	134	14.6	8.7	72	5.8	---	0.3	98	80	6.0	2.0	---	0.02	0.34	0.22	0.01	<.01	<.01	<.01	---	---	<.01	<.001
Tom Miner Creek	WQB	10/1/74	---	28.0	7.69	165	129	---	<1	11.4	---	---	14.6	8.2	70	5.3	---	0.3	94	77	5.0	1.7	---	0.04	<.03	0.35	0.11	<.01	0.01	<.01	<.001	0.10	<.01	<.001
Rock Creek	WQB	9/11/74	7.1	0.82	8.30	186	149	---	3.0	10.4	2.5	56	18.3	7.3	76	11	---	0.6	97	79	13.6	2.0	---	0.03	0.18	0.20	0.10	<.01	<.01	<.01	---	---	<.01	<.001
Big Creek	WQB	6/18/73	5.0	50.0	8.00	61	57	4	---	10.4	2.3	6	8.0	1.6	26	5.0	---	0.4	37	30	4.5	0.4	0.05	0.14	0.22	0.23	---	0.14	0.01	0.07	<.01	---	---	<.01
Big Creek	WQB	9/11/74	5.5	---	8.35	112	89	---	5.0	10.5	2.0	2	12.2	4.1	47	3.8	---	0.2	61	50	6.0	1.9	---	0.01	0.34	0.03	<.01	0.01	<.01	<.01	---	---	<.01	<.001
Emigrant Creek	WQB	6/17/74	10.0	---	7.30	246	60	140	1400	---	---	---	9.1	2.2	32	2.4	1.6	0.2	31	25	11.9	1.3	0.10	0.36	0.09	22	3.0	0.73	0.76	---	0.005	---	---	0.002
Mill Creek	WQB	9/12/74	7.0	29.1	8.35	188	154	---	0.5	10.4	1.8	0	22	9.1	92	4.6	---	0.2	106	87	11.6	1.1	---	0.01	0.15	0.05	0.01	0.02	<.01	<.01	---	---	<.01	<.001
Billman Creek	WQB	9/12/74	9.2	4.6	8.50	465	378	---	5.5	10.4	2.5	820	50	17.6	196	24	---	0.7	225	193	51	5.0	---	0.03	0.24	0.34	0.02	<.01	<.01	<.01	0.004	---	<.01	<.001
Big Timber Creek	WQB	10/1/74	---	33.4	8.26	759	604	---	<1	9.5	---	---	67	17.9	240	71	---	2.0	351	288	89	8.5	---	0.12	0.15	0.14	0.01	<.01	<.01	<.01	0.009	<.10	<.01	<.001
Otter Creek	WQB	10/1/74	---	20.6	8.03	329	279	---	4.0	10.4	---	---	48	7.4	151	12	---	0.4	191	159	18.0	0.5	---	0.0	0.21	0.74	0.06	<.01	<.01	<.01	<.001	<.10	<.01	<.001
Carey Irrigation Project																																		
Pond	WQB	8/16/74	15.8	---	8.20	506	401	---	---	---	---	---	36	12.1	140	53	---	1.9	206	183	79	5.8	0.30	0.04	---	---	---	---	---	---	---	---	---	---
Canal	WQB	8/16/74	18.8	---	8.30	307	257	---	---	---	---	---	33	9.0	121	17	---	0.7	160	137	31	2.5	0.14	0.05	---	2.3	0.02	0.05	0.01	<.01	<.001	---	<.01	---
Upper Deer Creek	FG	Minimum	6.1	---	8.3	---	161	5	---	9.8	---	---	28	4.3	87	3.4	0.4	---	100	82	12.2	0.3	0.0	0.0	---	0.01	0.0	<.01	<.02	---	---	---	---	<.01
Upper Deer Creek	FG	Mean	8.4	---	8.5	---	195	8	---	10.0	---	---	34	5.2	106	4.8	0.4	---	120	99	16.7	0.4	0.0	0.1	---	0.17	0.0	<.01	<.02	---	---	---	---	<.01
Upper Oeer Creek	FG	Maximum	9.5	---	8.6	---	244	13	---	10.3	---	---	42	6.3	123	6.8	0.5	---	149	123	24	0.6	0.0	0.2	---	0.37	0.0	<.01	<.02	---	---	---	---	<.01
Lower Oeer Creek	FG	Minimum	5.6	---	8.4	---	137	0	---	9.8	---	---	23	3.4	71	3.0	0.3	---	84	69	9.5	0.2	0.0	0.0	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Lower Oeer Creek	FG	Mean	6.7	---	8.4	---	162	3	---	10.2	---	---	27	4.1	85	4.0	0.3	---	91	80	13.3	0.7	0.0	0.3	---	0.06	0.0	<.02	<.02	---	---	---	---	<.01
Lower Deer Creek	FG	Maximum	8.5	---	8.5	---	205	5	---	10.5	---	---	35	5.0	107	5.8	0.4	---	123	101	19.0	1.6	0.0	0.7	---	0.10	0.01	<.02	<.02	---	---	---	---	<.01
Bridger Creek	WQB	9/28/73	16.0	2.1	8.00	351	308	<.9	---	10.5	1.7	106	54	9.2	172	11	---	0.4	216	177	16.9	1.5	0.13	0.20	<.01	0.95	---	0.47	0.07	0.39	<.01	---	---	<.01

Samples analyzed by the Water Quality Bureau, the Montana Department of Fish and Game, and the United States Geological Survey for the following constituetns were less than the listed figures (mg/l): Ag--<.002: Hg--<.002; Mo--<.1, Ni--<.05; Se--<.005; and V--<.05; all Ba, Be, and Co concentrations were equal to 0 mg/l.

streams are consistently near saturation and vary from 8.4 to 13.0 mg/l primarily as a function of temperature rather than of organic loading. Low BOD concentrations and generally low fecal coliform counts confirm the absence of extensive organic and municipal pollution in the sub-basin. Values of pH also vary, but were found to commonly reside between 7.0 and 8.0. Neither extremely high (greater than 9.0) nor extremely low (less than 6.0) pH values were obtained for this section of the river or for its tributaries. Both dissolved oxygen and pH are well within the critical values needed to support an active game fishery (Ref. 7).

Metals tests show that only iron and manganese occasionally exceeded the criteria and standards summarized in Table 9. In the Yellowstone River, fluoride levels were occasionally greater than the threshold concentrations for stock water but were in no cases in excess of standards established for human consumption given the temperature regime of the region (Ref. 5). None of the common constituents exceeded the recommended levels of Table 9. In some cases, dissolved solids, fecal coliforms, and turbidity values were greater than the desirable criteria for public supplies, but these were typically less than the maximum levels deemed permissible for this use (Ref. 6).

Shields River Sub-basin

Water quality data recently collected by the Montana Water Quality Bureau is the only information readily available for this particular sub-basin. This information is summarized in Table 11. The USGS has had no water quality monitoring sites in this region; their flow monitoring site at Clyde Park was discontinued in September 1967.

The water of the Shields River can be classified as non-saline while generally ranging from moderately hard to hard (Ref. 15). Along with total hardness, dissolved solid concentrations in the Shields River are slightly higher than those in the Yellowstone River. This coupled with generally higher suspended sediment, turbidity, and specific conductance values would indicate that the quality of water in the Shields is somewhat inferior to that of the mainstem Yellowstone River. In addition, the concentrations of metals, particularly iron, manganese, and zinc, were found to be higher in this tributary stream. Values of pH were typically above 8.0 but not extremely high. Like the Yellowstone River, BOD's were less than 3.0 mg/l; temperatures ranged from 0.0 to 18.0°C depending upon season with dissolved oxygen concentrations near saturation and varying with temperature. As a result, the Shields River provides the requisite conditions for a viable, cold water fishery. In general, the water quality in this sub-basin is relatively good in comparison to that in the Middle and Lower Yellowstone River Basins.

The Shields River is somewhat different from the Yellowstone River in its calcium-bicarbonate composition and in its relatively insignificant fluoride and potassium content. Sodium and sulfate are secondary ions in this stream with magnesium best described as a tertiary component.

Table 11

Typical Chemical Analyses of Water in the Shields River Sub-basin (43A) and in the Boulder River Sub-basin (43BJ)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO3	TA	SO4	Cl	F	NO3	PO4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Shields River Mainstem and Tributary																																		
Smith Creek	WQB	6/25/73	14.0	10.0	7.50	165	144	4	---	---	---	---	22	4.5	74	9.2	---	0.5	99	81	8.5	0.1	0.29	0.12	0.01	0.25	---	0.06	0.03	0.81	<.01	---	---	<.01
Shields River:																																		
nr Wilsall	WQB	6/25/73	12.5	17.5	7.10	110	91	2	---	---	---	---	16	2.0	48	6.0	---	0.4	60	50	6.3	0.1	0.10	0.13	<.01	0.10	---	0.34	0.04	0.59	<.01	---	---	<.01
nr Clyde Park	WQB	6/6/73	12.0	30.0	8.50	379	326	25	---	9.5	---	---	51	10.0	167	21	---	0.7	212	194	23	2.0	0.20	0.48	---	0.65	---	<.01	0.01	<.01	<.01	---	---	<.01
nr Clyde Park	WQB	6/25/73	18.0	40E	8.50	397	340	15	34	---	---	---	51	11.0	171	26	---	0.9	208	204	29	4.3	0.22	0.16	<.01	0.74	---	0.83	0.04	0.06	<.01	---	---	<.01
nr Livingston	WQB	9/28/73	15.5	55E	8.30	453	365	8	---	11.0	2.0	330	54	9.9	175	25	---	0.8	243	199	28	4.5	0.21	0.02	0.01	0.30	---	0.22	<.01	<.01	<.01	---	---	<.01
nr Livingston	WQB	12/21/73	0.2	150E	8.10	433	374	<1	---	---	2.2	79	57	10.9	186	23	---	0.7	246	202	33	3.6	0.19	1.0	0.03	0.13	---	0.01	0.01	<.01	<.01	---	---	<.01
nr Livingston	WQB	3/27/74	4.0	140E	7.70	310	251	---	---	---	---	1100	38	8.7	132	13	3.7	0.5	156	128	23	4.6	0.08	3.1	0.48	17	0.95	0.07	0.03	---	0.01	---	---	<.001
nr Livingston	WQB	4/25/74	---	160E	8.20	272	224	---	---	---	---	2400	38	6.5	121	9.6	0.0	0.4	149	123	17.8	2.2	---	0.80	0.15	16	0.69	0.04	0.02	---	0.002	---	---	<.001
nr Livingston	WQB	6/17/74	15.1	700E	8.00	80	203	210	440	7.1	---	---	35	4.6	108	8.2	---	0.3	140	115	12.4	1.6	0.13	0.42	0.11	13	0.71	0.03	<.01	---	0.004	---	---	<.001
nr Livingston	WQB	10/1/74	---	149	8.18	455	378	---	---	11.5	---	---	55	12.1	187	25	---	0.8	242	202	37	4.5	---	0.44	0.15	0.34	0.02	0.03	<.01	<.01	<.001	<.10	<.01	<.001
Samples analyzed by the Water Quality Bureau for Vanadium were less than 0.05 mg/l.																																		
Boulder River Mainstem																																		
nr headwaters	WQB	7/29/69	14.0	18.5	7.3	---	---	1.6	---	9.0	---	---	6.0	3.0	28	---	---	---	---	40	0.0	3.7	0.35	0.003	0.15	0.02	0.1	---	0.01	---	---	---	0.02	---
nr headwaters	SRT	1/7/71	---	112	7.3	61	---	---	---	---	---	---	7.8	2.1	28	2.2	0.8	0.2	30	25	6	0.5	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
nr headwaters	SRT	3/17/71	---	14	7.5	67	---	---	---	---	---	---	3.4	2.8	20	2.4	0.5	0.2	35	29	1	0.1	0.0	0.0	0.05T	0.0	0.0	0.010	---	---	0.002	---	0.005	0.010
nr headwaters	SRT	1/7/71	---	153	7.4	68	---	---	---	---	---	---	7.2	2.1	27	2.6	1.3	0.2	37	30	6	0.2	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
nr headwaters	SRT	5/17/71	---	30	7.6	82	---	---	---	---	---	---	4.4	4.3	29	2.4	0.8	0.2	40	33	2	0.3	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
at Fleming Bridge	WQB	7/30/69	13.5	312	7.3	---	---	0.4	---	9.0	---	---	7.0	1.8	25	---	---	---	---	33	2.0	2.5	0.2	0.003	0.09	0.02	0.2	---	0.01	---	---	---	0.02	---
at Fleming Bridge	SRT	6/30/71	4.0	---	7.0	52	---	---	---	---	---	---	6.9	1.2	22	1.9	1.3	0.2	25	21	4	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
at Fleming Bridge	SRT	7/27/71	10.2	700	7.3	50	---	---	---	---	---	---	5.5	1.8	21	1.7	1.1	0.2	24	19	9	0.4	0.0	0.1	---	0.0	0.0	0.010	---	---	---	---	---	---
at Fleming Bridge	SRT	8/17/71	---	---	7.3	64	---	---	---	---	---	---	3.6	2.0	17	1.8	1.2	0.2	32	26	1	0.1	0.0	0.0	0.05T	0.001	0.13	---	---	---	0.002	---	0.005	0.010
at Fleming Bridge	SRT	10/26/71	---	---	7.3	79	---	---	---	---	---	---	8.9	2.4	32	2.2	1.0	0.2	37	30	4	0.4	0.12	0.1	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
at Fleming Bridge	SRT	11/14/71	2.2	---	7.8	100	---	---	---	---	---	---	14.2	2.2	44	2.1	1.5	0.1	46	37	9	0.5	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
at Fleming Bridge	SRT	12/17/71	-0.6	---	7.6	87	---	---	---	---	---	---	11.2	2.6	38	2.4	1.2	0.2	40	33	10	0.5	0.0	0.4	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
at Fleming Bridge	SRT	3/16/72	6.5	46	7.9	92	---	---	---	---	---	---	10.7	3.2	40	2.8	1.2	0.2	45	37	9	0.2	0.0	0.0	---	0.0	0.0	0.101	---	---	0.002	---	0.005	0.010
at Fleming Bridge	FG	Minimum	-0.6	---	8.2	---	45	0	---	9.1	---	---	4.8	1.4	20	1.0	0.6	---	24	20	2.6	0.1	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
at Fleming Bridge	FG	Mean	5.0	---	8.4	---	65	1	---	10.7	---	---	8.7	2.2	31	2.0	1.0	---	36	30	5.8	0.4	0.01	0.3	---	0.07	0.0	<.01	<.01	---	---	---	---	<.01
at Fleming Bridge	FG	Maximum	11.2	---	8.7	---	86	7	---	12.0	---	---	14.2	2.8	44	2.8	1.5	---	47	39	10.4	0.6	0.12	0.7	---	0.27	0.01	0.01	<.01	---	---	---	---	<.01
abv Clydehurst River	SRT	3/23/71	0.0	30	7.5	---	36	---	---	---	---	---	11.2	1.9	83	3.0	---	---	55	45	11	1.0	---	0.004	---	0.0	0.001	0.006	0.002	0.005	---	---	0.005	0.001
abv Clydehurst River	SRT	6/25/71	6.7	---	7.4	30	32	---	---	---	---	---	1.0	7.1	43	1.4	---	---	29	24	3	1.0	---	0.1	---	0.001	0.058	0.042	0.009	0.006	0.004	---	0.010	0.005
nr Falls Creek Campground	SRT	3/23/71	0.0	0.3	7.8	---	36	---	---	---	---	---	8.0	3.9	78	2.7	---	---	49	40	12	1.0	---	1.0	0.23T	0.0	0.002	0.046	0.020	0.006	---	---	0.005	0.001
nr Falls Creek Campground	SRT	4/15/71	4.4	18	7.1	100	---	---	---	---	---	---	9.5	2.1	32	2.8	2.1	0.2	41	34	3	1.0	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
nr Falls Creek Campground	SRT	6/10/71	5.6	925	7.0	43	---	---	---	---	---	---	6.8	0.8	20	1.6	1.3	0.2	24	19	3	2.0	0.10	0.0	---	0.001	0.030	0.010	0.010	---	---	---	---	---
nr Falls Creek Campground	SRT	7/27/71	10.7	825	7.2	50	---	---	---	---	---	---	5.6	1.6	21	1.7	1.2	0.2	23	19	5	0.4	0.0	0.0	---	0.0	0.0	0.010	---	---	---	---	---	---
nr Falls Creek Campground	SRT	2/17/72	1.1	---	7.4	100	---	5	---	---	---	---	13.2	2.0	41	2.6	1.4	0.2	54	44	5	1.0	0.0	0.2	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
nr Falls Creek Campground	SRT	3/17/72	---	80	7.8	95	---	---	---	---	---	---	13.8	1.3	39	2.5	1.2	0.2	44	36	9	0.1	0.0	0.1	---	0.0	0.0	0.010	---	---	0.002	---	0.005	0.010
nr Contact	SRT	6/30/71	---	878	7.4	57	---	---	---	---	---	---	6.9	1.6	24	1.7	1.3	0.2	29	24	4	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
nr Contact	SRT	8/16/71	14.0	280	7.8	79	---	---	---	---	---	---	6.2	2.8	27	1.8	1.3	0.2	38	31	4	0.2	0.0	0.0	0.05T	0.001	0.0	0.010	0.010	---	0.002	---	0.005	0.010
nr Contact	USGS	10/21/70	4.5	128	---	---	---	---	---	---	---	---	---	3.3	---	---	---	---	---	---	---	---	---	---	---	0.02	0.0	---	0.0	0.0	0.0	0.0	0.0	0.0
nr Contact	USGS	6/17/71	12.0	2890	---	---	---	---	70	---	---	---	---	1.6	---	---	---	---	---	---	---	---	---	---	---	0.04	0.02	0.010	0.003	0.004	0.001	0.0	0.0	0.0
nr Contact	USGS	9/23/71	8.0	155	---	---	---	---	1	---	---	---	---	3.2	---	---	---	---	---	---	---	---	---	---	---	0.03	0.0	0.010	0.002	0.0	0.008	0.01	0.0	0.0
nr Contact	USGS	1/31/72	0.0	62	---	---	---	---	3	---	---	---	---	4.0	---	---	---	---	---	---	---	---	---	---	---	0.04	0.0	0.010	0.002	0.003	0.0	0.0	0.0	0.001
nr Contact	USGS	6/5/72	6.5	2620	---	---	---	---	56	---	---	---	---	1.5	---	---	---	---	---	---	---	---	---	---	---	0.04	0.0	0.0	0.007	0.003	0.0	0.02	0.0	0.0
nr Contact	USGS	10/24/72	5.0	200	---	---	---	---	2	---	---	---	---	3.3	---	---	---	---	---	---	---	---	---	---	---	0.04	0.02	0.020	0.008	0.002	0.006	0.25	0.0	0.001
nr Contact	USGS	1/24/73	0.5	44	---	---	---	---	4	---	---	---	---	4.7	---	---	---	---	---	---	---	---	---	---	---	0.03	0.0	0.020	0.005	0.0	0.0	0.03	0.0	0.0
nr Contact	USGS	6/25/73	8.5	1600	---	---	---	---	26	---	---	---	---	1.6	---	---	---	---	---	---	---	---	---	---	---	0.11	0.0	0.070	0.011	0.002	0.001	0.0	0.0	0.001
at Big Timber	WQB	10/1/74	---	306	8.31	274	220	---	---	9.9	---	---	36	10.0	131	5.1	---	0.2	133	109	36	0.1	---	0.09	0.21	0.12	0.08	<.01	<.01	<.01	<.001	<.10	<.01	<.001
at Big Timber	WQB	7/31/69	10.5	505	7.2	---	---	0.5	---	10.0	---	---	7.6	2.6	30	---	---	---	---	35	2.0	2.5	0.1	0.0	0.09	0.04	0.01	---	0.0	---	---	---	0.03	---
Boulder River Tributaries																																		
Basin Creek	WQB	7/29/69	10.0	3.1	7.3	---	---	0.4	---	10.0	---	---	8.0	1.2	25	---	---	---	---	25	6.0	2.5	0.15	1.0	0.08	0.04	0.2	---	0.06	---	---	---	0.04	---
Copper Creek	WQB	7/29/69	13.0	5.4	7.65	---	---	1.0	---	8.0	---	---	9.0	6.0	48	---	---	---	---	60	1.5	2.5	0.14	0.0	0.24	0.08	0.1	---	0.0	---	---	---	0.04	---
East Fork	WQB	7/30/69	8.5	160E	7.3	---	---	0.4	---	9.0	---	---	4.0	1.8	18	---	---	---	---	25	0.0	2.5	0.13	0.007	0.06	0.05	0.2	---	0.05	---	---	---	0.03	---
Fourmile Creek	WQB	7/31/69	9.0	---	7.45	---	---	0.4	---	10.0	---	---	10.0	2.4	35	---	---	---	---	40	2.0	2.5	.2	0.0	0.14	0.05	0.0	---	0.0	---	---	---	0.035	---
East Chippy Creek	FG	Minimum	0.0	---	8.2	---	54	0	---	10.5	---	---	8.3	3.0	33	0.8	0.6	---	33	27	6.8	0.3	0.0	0.1	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
East Chippy Creek	FG	Maximum	4.5	---	8.5	---	84	1	---	12.1	---	---	10.8	4.1	44	0.8	0.7	---	42	34	14.3	0.4	0.0	0.8	---	0.02	0.0	0.015	0.01	---	---	---	---	<.01
Bobcat Creek	SRT	6/30/71	5.0	39	7.6	63	---	---	---	---	---	---	6.2	2.7	26	1.1	1.0	0.1	23	19	6	0.1	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
Bobcat Creek	SRT	8/17/71	8.0	4	7.5	85	---	---	---	---	---	---	5.4	3.4	27	1.3	1.0	0.1	37	30	1	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Bobcat Creek	SRT	9/14/71	4.5	4	7.4	---	39	---	---	---	---	---	10.2	3.4	60	1.2	0.5	---	42	35	2	0.2	0.06	0.1	0.0T	0.0	0.0	0.016	0.020	0.010	0.001	---	0.005	0.002
Bobcat Creek	SRT	3/16/72	4.0	2	7.8	112	---	---	---	---	---	---	15.3	2.8	49	1.4	1.2	0.1	48	39	13	0.2	0.0	0.0	---	0.0	0.0	0.010	---	---	0.002	---	0.005	0.010
Blakely Creek	SRT	6/30/71	7.0	4	7.7	85	---	---	---	---	---	---	9.2	5.0	44	1.3	0.7	0.1	48	39	5	0.4	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	---	0.010
Blakely Creek	SRT	8/16/71	13.0	0.4	8.1	127	---	---	---	---	---	---	8.2	8.0	54	1.3	0.6	0.1	72	59	3	0.3	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	---	0.010
Blakely Creek	SRT	9/14/71	4.5	0.5	8.3	---	64	---	---	---	---	---	13.6	7.4	104	1.2	0.5	---	77	68	2	0.3	0.0	0.1	0.05T	0.0	0.0	0.015	0.003	0.010	0.001	---	0.007	0.002
Blakely Creek	SRT	3/16/72	---	0.2	8.0	138	---	---	---	---	---	---	15.4	7.6	70	1.0	0.5	0.1	77	63	9	0.2	0.0	0.0	---	0.0	0.0	0.010	---	---	0.002	---	0.005	0.010
Blakely Creek	FG	Minimum	0.0	---	8.3	---	81	0	---	10.2	---	---	9.9	4.9	45	1.0	0.3	---	50	41	4.4	0.6	0.0	0.1	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Blakely Creek	FG	Maximum	6.2	---	8.5	---	114	0	---	11.9	---	---	12.2	8.0	63	1.4	0.3	---	74	61	6.3	0.7	0.0	0.2	---	0.02	0.1	0.01	<.01	---	---	---	---	<.01
Graham Creek	SRT	6/30/71	8.0	14	7.6	63	---	---	---	---	---	---	6.2	3.6	30	1.7	0.5	0.1	34	28	0.4	0.3	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
Graham Creek	SRT	3/17/72	3.5	0.3	8.0	123	---	---	---	---	---	---	17.7	2.8	55	2.2	0.3	0.1	68	56	4	0.2	0.0	0.0	---	0.0	0.0	0.010	---	---	0.002	---	0.005	0.010
Graham Creek	FG	Minimum	0.0	---	8.1	---	40	0	---	10.3	---	---	9.9	1.9	32	1.3	0.2	---	38	31	3.2	0.5	0.0	0.0	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Graham Creek	FG	Maximum	4.5	---	8.5	---	99	1	---	11.6	---	---	13.7	3.8	49	2.2	0.2	---	61	50	5.4	0.7	0.0	0.4	---	0.05	0.0	0.01	<.01	---	---	---	---	<.01
Great Falls Creek	FG	Minimum	0.0	---	7.8	---	34	0	---	10.1	---	---	4.2	0.0	14	1.1	0.9	---	14	11	6.6	0.2	0.0	0.0	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Great Falls Creek	FG	Maximum	4.5	---	8.4	---	47	2	---	10.6	---	---	6.4	0.8	16	2.1	0.9	---	16	13	11.6	0.3	0.0	0.6	---	0.08	0.0	0.01	<.01	---	---	---	---	<.01
Falls Creek	SRT	3/23/71	0.0	150	7.8	---	24	---	---	---	---	---	8.0	1.0	61	3.3	---	---	30	25	16	1.0	0.14	0.7	---	0.0	0.006	0.009	0.015	0.009	---	---	0.005	0.001
Falls Creek	SRT	6/25/71	5.6	---	7.1	---	14	---	---	---	---	---	4.6	0.6	37	1.0	---	---	16	14	13	0.0	0.02	0.8	---	0.0	0.004	0.030	0.001	0.002	0.001	---	0.010	0.005
Falls Creek	SRT	11/4/71	0.0	---	7.5	---	24	---	---	---	---	---	8.0	1.0	50	1.6	1.3	---	26	22	9	3	0.08	0.2	---	0.0	0.0	0.005	0.005	0.010	0.001	---	0.010	0.005
Falls Creek	FG	Minimum	0.0	---	8.4	---	35	0	---	10.5	---	---	4.6	1.0	15	1.1	0.9	---	17	14	4.0	0.2	0.0	0.2	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Falls Creek	FG	Maximum	4.5	---	8.4	---	56	2	---	11.8	---	---	7.9	1.2	24	3.0	1.0	---	22	18	12.0	1.5	0.0	0.8	---	0.09	0.0	0.01	0.01	---	---	---	---	<.01
Froze-to-Death Creek	SRT	3/23/71	0.0	300	7.5	---	40	---	---	---	---	---	12.8	1.9	80	1.8	---	---	49	40	14	0.0	0.11	0.2	---	0.0	0.002	0.008	0.004	0.005	---	---	0.005	0.001
Froze-to-Death Creek	SRT	6/25/71	7.3	---	7.2	---	14	---	---	---	---	---	4.8	0.5	41	1.0	---	---	24	20	11	0.0	0.04	0.1	---	0.0	0.001	0.026	0.016	0.004	0.001	---	0.010	0.005
Froze-to-Death Creek	SRT	11/4/71	0.0	---	7.5	---	32	---	---	---	---	---	0.0	2.9	65	1.2	1.1	---	36	30	12	3	0.12	0.2	---	0.0	0.026	0.005	0.005	0.010	0.004	---	0.010	0.005

Table 11
(Continued)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
East Boulder River and Tributaries																																		
nr headwaters	SRT	7/20/71	13.4	10	7.1	26	---	0.5	26	----	---	----	1.1	0.9	7	1.4	0.7	0.2	12	10	1.0	1.0	0.0	0.0	0.05T	0.020	0.0	----	0.010	----	0.002	---	0.005	0.010
nr headwaters	SRT	7/28/71	14.1	8	8.5	49	---	----	---	----	---	----	6.2	1.2	21	1.4	0.6	0.1	24	21	6	0.4	0.0	0.1	----	----	0.0	0.010	----	----	----	---	----	----
nr headwaters	SRT	9/15/71	3.9	4	7.4	36	---	0.4	34	----	---	----	1.5	1.6	10	1.6	0.7	0.2	18	15	0.4	1.0	0.0	0.0	0.05T	0.030	0.0	----	0.010	----	0.002	---	0.005	0.010
nr headwaters	SRT	7/20/71	11.2	3	7.0	35	---	0.7	35	----	---	----	1.5	2.7	---	0.5	0.1	---	22	18	1.0	0.3	----	----	----	0.070	----	----	0.002	----	----	---	0.005	----
nr headwaters	SRT	9/15/71	2.8	2	7.2	66	---	0.4	47	----	---	----	1.8	6.3	---	0.6	0.2	---	39	32	3	0.4	----	----	----	0.040	----	----	0.001	----	----	---	0.005	----
nr headwaters	FG	Minimum	6.7	------	7.4	---	30	0	---	8.0	---	----	2.0	1.2	11	1.4	0.5	---	13	11	0.3	0.3	0.0	0.1	----	0.0	0.0	----	----	----	----	---	----	----
nr headwaters	FG	Mean	10.6	------	7.9	---	35	2	---	8.7	---	----	3.8	1.4	15	1.4	0.6	---	17	14	2.6	0.6	0.0	0.4	----	0.03	0.0	----	----	----	----	---	----	----
nr headwaters	FG	Maximum	14.0	------	8.6	---	44	5	---	9.4	---	----	6.3	1.6	21	1.5	0.6	---	24	21	5.6	1.2	0.0	0.8	----	0.10	0.01	----	----	----	----	---	----	----
blw Canyon Creek	SRT	8/10/71	----	27.2	7.18	49	---	----	---	----	---	----	3.8	1.5	16	1.9	0.6	0.2	25	20	2.0	0.4	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	----	0.002	---	0.005	0.010
at Anderson Springs	WQB	7/31/69	12.0	109	7.8	---	---	0.4	---	10.0	---	----	24.0	5.4	83	----	---	---	---	85	3.0	2.5	0.18	0.003	0.11	0.04	0.2	----	0.01	----	----	---	0.02	----
at Anderson Springs	SRT	4/15/71	5.0	17	7.9	223	---	----	---	----	---	----	29.0	6.4	98	2.0	1.0	0.1	119	97	2	0.5	0.0	0.0	----	0.0	0.0	----	----	----	----	---	----	----
at Anderson Springs	SRT	6/10/71	4.8	100	7.5	75	---	----	---	----	---	----	11.1	2.0	35	1.0	0.6	0.1	36	29	9	1.0	0.1	0.0	----	0.0	0.010	0.010	0.010	----	----	---	----	----
at Anderson Springs	SRT	7/27/71	9.5	70	8.2	160	---	----	---	----	---	----	24.0	5.2	79	1.6	0.7	0.1	92	75	8	0.5	0.0	0.0	----	0.0	0.0	0.010	----	----	----	---	----	----
at Anderson Springs	SRT	9/16/71	4.0	12	7.6	193	---	----	---	----	---	----	26.0	7.4	94	1.7	0.6	0.1	112	92	5	1.0	0.0	0.0	0.05T	0.0	0.0	----	0.010	----	0.002	---	0.005	0.010
at Anderson Springs	SRT	10/26/71	3.9	------	8.0	183	---	----	---	----	---	----	26.0	6.9	93	1.9	0.5	0.1	102	84	14	0.4	0.0	0.2	----	0.0	0.0	0.010	0.010	----	----	---	----	0.010
at Anderson Springs	SRT	1/17/72	1.7	------	8.0	206	---	----	---	----	---	----	32.0	5.5	103	1.6	0.6	0.1	119	97	9	0.2	0.0	0.0	----	0.0	0.0	0.010	0.010	----	----	---	----	0.010
at Anderson Springs	SRT	3/17/72	8.0	22	8.3	208	---	----	---	----	---	----	31.0	7.0	106	1.5	0.5	0.1	115	101	14	0.2	0.0	0.1	----	0.0	0.0	0.010	----	----	0.002	---	0.005	0.010
at Anderson Springs	FG	Minimum	0.0	------	8.0	---	63	0	---	9.2	---	----	10.4	2.0	35	0.8	0.2	---	36	29	1.8	0.0	0.0	0.0	----	0.0	0.0	<.01	<.01	----	----	---	----	<.01
at Anderson Springs	FG	Mean	4.5	------	8.5	---	142	1	---	11.0	---	----	23.8	5.7	82	1.4	0.5	---	89	78	7.0	0.3	0.0	0.1	----	0.02	0.0	<.01	<.01	----	----	---	----	<.01
at Anderson Springs	FG	Maximum	11.2	------	8.6	---	180	5	---	12.1	---	----	32.0	6.9	105	2.0	1.0	---	122	104	12.2	1.0	0.1	0.8	----	0.17	0.1	0.01	<.01	----	----	---	----	<.01
at Ewan Ranch	SRT	4/15/71	6.7	19	8.0	419	---	----	---	----	---	----	50	14.5	183	12.7	2.5	0.4	179	147	51	1.0	0.0	0.0	----	----	----	0.0	----	----	----	---	----	----
at Ewan Ranch	SRT	6/10/71	7.8	80	7.6	120	---	----	---	----	---	----	17.9	3.2	57	1.7	0.9	0.1	59	48	9	1.0	0.1	0.0	----	----	0.030	0.010	0.010	----	----	---	----	----
at Ewan Ranch	SRT	7/27/71	14.2	60	8.2	261	---	----	---	----	---	----	36	9.1	126	3.2	1.4	0.1	130	106	26	3	0.0	0.2	----	----	0.0	0.010	----	----	----	---	----	----
at Ewan Ranch	SRT	9/15/71	7.8	65	8.6	---	202	----	---	----	---	----	56	15.5	303	4.2	0.6	---	161	164	55	0.3	0.24	0.2	0.0T	----	0.0	0.008	0.016	0.015	0.001	---	0.005	0.002
at Ewan Ranch	SRT	11/4/71	1.1	------	8.4	---	145	----	---	----	---	----	36	13.6	224	2.9	1.0	---	112	112	51	2	0.24	0.3	----	----	0.0	0.005	0.005	0.010	0.001	---	0.010	0.005
at Ewan Ranch	SRT	12/17/71	0.6	64	8.2	357	---	----	---	----	---	----	50	13.6	180	4.5	1.2	0.1	166	136	50	0.5	0.0	0.7	----	----	0.0	0.010	0.010	----	----	---	----	0.010
at Ewan Ranch	SRT	2/17/72	1.1	------	8.1	385	---	0	---	----	---	----	55	13.2	190	5.7	1.5	0.2	173	142	57	0.5	0.0	1.0	----	----	0.0	0.010	0.010	----	----	---	----	0.010
nr mouth	FG	Minimum	0.6	------	7.6	---	98	0	---	9.3	---	----	17.9	3.2	57	1.6	0.5	---	59	48	9.4	0.3	0.0	0.0	----	0.0	0.0	<.01	<.01	----	----	---	----	<.01
nr mouth	FG	Mean	5.6	------	8.4	---	253	4	---	11.1	---	----	41.6	9.5	150	4.8	1.2	---	141	116	44.0	1.4	0.0	0.3	----	0.11	0.0	<.01	<.01	----	----	---	----	<.01
nr mouth	FG	Maximum	14.6	------	8.7	---	325	20	---	12.4	---	----	55.0	15.3	196	12.7	2.5	---	178	158	63.0	3.3	0.2	1.0	----	0.55	0.02	0.015	<.01	----	----	---	----	<.01
Unnamed Creek	FG	Minimum	6.7	------	7.3	---	35	0	---	8.4	---	----	1.3	3.2	17	0.7	0.2	---	20	16	2.0	0.2	0.0	0.0	----	0.0	0.0	<.01	<.02	----	----	---	----	<.01
Unnamed Creek	FG	Mean	8.4	------	7.9	---	44	7	---	9.0	---	----	3.4	3.3	22	0.8	0.3	---	23	19	4.0	0.6	0.0	0.2	----	0.04	0.0	<.01	<.02	----	----	---	----	<.01
Unnamed Creek	FG	Maximum	10.1	------	8.5	---	49	13	---	9.8	---	----	4.9	3.4	25	0.9	0.4	---	27	22	6.3	1.0	0.0	0.5	----	0.10	0.0	<.01	<.02	----	----	---	----	<.01
Unnamed Creek	SRT	7/20/71	11.2	3	7.00	39	---	2.7	35	----	---	----	1.5	2.7	---	0.5	0.1	---	22	18	1	0.3	----	----	----	0.070	----	----	0.002	----	----	---	0.005	----
Unnamed Creek	SRT	9/15/71	2.8	2	7.20	71	---	1.5	47	----	---	----	1.8	6.3	---	0.6	0.2	---	39	32	3	0.4	----	----	----	0.040	----	----	0.001	----	----	---	0.005	----
Brownlee Creek:																																		
at headwaters	SRT	7/20/71	7.3	0.3	7.10	49	---	1.2	30	----	---	----	1.8	4.6	---	0.2	0.1	---	22	18	0.4	0.0	----	----	----	0.040	----	----	0.004	----	----	---	0.006	----
at headwaters	SRT	9/15/71	2.8	1	7.00	28	---	3.1	24	----	---	----	1.1	2.1	---	0.2	0.1	---	14	12	1.0	0.1	----	----	----	0.050	----	----	0.001	----	----	---	0.004	----
nr mouth	SRT	8/10/71	----	7.0	7.02	41	---	----	---	----	---	----	3.0	1.7	14	0.8	0.3	0.1	16	13	1.6	0.7	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	----	0.002	---	0.005	0.010
Creek abv Camp L.	SRT	7/21/71	8.0	10.0	6.54	14	---	----	---	----	---	----	1.2	0.1	3	0.8	1.0	0.2	7	6	1.2	0.3	0.0	0.0	0.05T	0.0	0.0	----	0.010	----	0.002	---	0.005	0.010
Canyon Creek	SRT	8/10/71	----	4.4	7.21	54	---	----	---	----	---	----	7.8	0.7	22	1.2	0.4	0.1	28	23	2.4	0.4	0.0	0.5	0.05T	0.0	0.0	0.010	0.010	----	0.002	---	0.005	0.010
West Boulder River	WQB	7/31/69	13.0	297	7.4	----	---	1.5	---	9.0	---	----	9.0	1.8	30	----	---	---	---	40	2.0	2.5	0.26	0.0	0.04	0.0	0.0	----	0.02	----	----	---	0.02	----
West Boulder River	SRT	9/16/71	4.0	145	7.24	87	---	----	---	----	---	----	9.6	2.5	34	1.4	1.3	0.1	40	33	4.8	0.6	0.0	0.0	0.05T	0.0	0.0	----	0.010	----	0.002	---	0.005	0.010

Samples analyzed for the following constituents were generally less than or equal to the listed values (mg/l): Al--<0.4; Ag--<0.002; Co--<0.002; Hg--<0.001; Mo--<0.005; Ni--<0.02; Se--<0.004; V--<0.05; Ba and Be--=0.0.

The quality of water is apparently best upstream in the Shields near Wilsall with dissolved constituents increasing downstream to its mouth. Smith Creek, a headwater stream, has a quality of water equal or better than that in downstream samples from the Shields *per se*. The quality of the Smith Creek sample, however, was somewhat inferior to that obtained from the Shields River near Wilsall on identical dates.

Iron and manganese concentrations in samples from this sub-basin commonly exceeded the recommended criteria for these metals (Table 9). In addition, standards for lead were exceeded in about 45% of the samples tested for this parameter. These features plus suspended sediment-turbidity probably represent the major factors detracting from the quality of water in the sub-basin. Dissolved solid concentrations were generally greater than that desirable for public supply (Ref. 6); however, values were considerably less than that deemed permissible for this use. Although fecal coliform counts were relatively high in the Shields River, these also were lower than the recommended criteria and standards for public supply in most cases (Ref. 6 and 7).

Boulder River Sub-basin

A great deal of water quality information from various sources is available for the Boulder River and its tributaries as summarized in Table 11. This river is one of four major tributaries entering the Yellowstone River in the Upper Yellowstone River basin. In contrast to various tributaries in the remaining portions of the river (e.g., Bighorn, Tongue, and Powder Rivers), the water in the Boulder is generally of better quality than that of the Yellowstone River mainstem. Along with the Shields and Stillwater Rivers, the Boulder River is unique in the Yellowstone River basin in having all of its drainage area in Montana.

The Boulder River is a soft, calcium bicarbonate type of water that generally has specific conductances less than 100 micromhos; in contrast, values from the Yellowstone typically exceed 100 micromhos. All dissolved constituents are present in low concentrations in the Boulder River with calcium generally less than 15 mg/l; sodium, potassium, and magnesium are found in nearly equal amounts at less than 5 mg/l. The waters are non-saline. Sulfate is apparently the major secondary ion in the river, but in concentrations commonly less than 10 mg/l. Chloride and fluoride are insignificant components of the Boulder water. A low metals content is common in waters of the Boulder River. These characteristics and the range of temperatures (0.0 to 14°C) and pH (7.0 to 8.0) in the river and its high dissolved oxygen concentrations are indicative of an excellent, cold water fishery. Low turbidities and suspended sediment concentrations are present in the river during low flow periods. With high flows, sediment increased but rarely exceeded 70 mg/l.

The East and West Boulder Rivers are major tributaries of the Boulder River in the sub-basin. In addition, some water quality data is available for several smaller streams that directly drain into the Boulder mainstem and into the East Boulder River (Table 11). With the exception of the East Boulder River, the chemical composition of water from these tributaries and their concentrations of common constituents are similar to those in samples from the main Boulder River. Metals concentrations in the smaller streams of the sub-basin are also quite low. As a result, the quality of water in these smaller streams is excellent, and they provide excellent trout habitat. The streams, however, have low alkalinity concentrations and buffering capacities are severely reduced. For example, comparing the typical flows and alkalinities of the Boulder River to those of the Yellowstone, nearly a 16-fold greater acid input could be introduced into the Yellowstone River than into the Boulder to produce a similar change in pH. Such acid discharge into the streams of the Boulder sub-basin is apparently not a factor at the present time. Ninety-nine percent of the samples collected from the basin had pH's in excess of 7.00.

No distinct trends in downstream water chemistry are evident in the data for the Boulder mainstem (Table 11). In contrast, dissolved constituents markedly increase downstream in the East Boulder River; as a result, the downstream reach of the East Boulder River appears to have the poorest quality of water in the sub-basin. Although metals concentrations are low, dissolved solid concentrations and specific conductances in the East Boulder are most similar to those of the Yellowstone River. The East Boulder River is also non-saline but is characterized by having moderately hard to hard waters dependent upon flow and reach. This river also has a calcium-bicarbonate-type of water, but with magnesium more prevalent and with higher concentrations of sulfate. Like the Boulder River mainstem, sodium, potassium, and chloride are insignificant components of the water with fluoride commonly absent. Alkalinities and pH are relatively high in the East Boulder River; the stream therefore would be better able to buffer wastewater inputs than other streams in the basin.

Turbidity and suspended concentrations are also greater in the East Boulder River than in other streams of the region. This river has a good to excellent quality of water with temperature, pH, and dissolved oxygen at levels requisite for a cold water fishery. Of the various water quality criteria and standards in Table 9, only the desirable criteria for dissolved solids in water for public supply was exceeded in about 20% of the samples obtained from the East Boulder River. None of the listed standards were violated by samples collected from other streams in the sub-basin.

Stillwater River Sub-basin

The Stillwater River drains the Absaroka and the Beartooth Ranges with its headwaters located at the foot of the Beartooth Plateau. Like the Boulder and Shields River, all of the drainage area of the Stillwater River is located in Montana. Major tributaries of the Stillwater are the West Fork, Fishtail Creek, and East and West Rosebud Creeks. Considerable water quality data are available for several reaches of the Stillwater mainstem and for various reaches of its major tributaries. In addition, data are available for numerous small tributary creeks that empty into these streams.

The USGS maintains flow measuring stations on the Stillwater River at Nye and downstream near Absarokee; their water quality site is located at Beehive. In addition, the USGS has had a water quality station on the river above the West Fork which monitored temperature, sediment, and discharge; similar sites were located on the West Fork near Nye and on Castle Creek. This agency also has a discharge measuring site on West Rosebud Creek near Roscoe; flow data is also available for Rosebud Creek near Absarokee (now discontinued). Considerable water quality data is available from a variety of other sources for this sub-basin (Table 12).

Surface water in the Stillwater River sub-basin has a composition similar to that of the Boulder River. Streams are of a calcium-bicarbonate composition with bicarbonate the most prevalent component and sodium, potassium, chloride, and fluoride minor constituents. Magnesium concentrations commonly are greater or closely equivalent to those of sodium. Sulfate concentrations were found to be similar depending upon stream and reach.

Waters of the sub-basin have low dissolved solid concentrations and are non-saline (Ref. 15). However, dissolved solids varied considerably between streams, between reaches of streams, and with flow. With the exception of the extreme upstream end of the Stillwater River (near its headwaters), dissolved solids were lowest in the upper reaches of major streams at high flow periods and were also low in small tributary creeks such as Nye, Cathedral, and Picket Pin Creeks. However, in the downstream reaches and in some smaller creeks (such as Silver, Little Rocky, and Initial Creeks) dissolved solids approached and occasionally exceeded 200 mg/l. Most typically, dissolved solids in the sub-basin ranged from 30 to 150 mg/l.

Some waters in the sub-basin can be classified as soft with low total hardness concentrations; this was true of upstream reaches of major streams and in some smaller tributaries (Goose Creek, Saderbalm Creek, and Fishtail Creek). Downstream and in other creeks such as Mountain View Creek, waters range from hard to moderately hard, and in a few cases, some waters are very hard. The Rosebud Creeks are distinct in their soft waters and low dissolved solids and probably possess the highest quality of water in the sub-basin.

In general, quality of water in the Stillwater River sub-basin is good to excellent. However, a few exceptions were found in the region. Iron, manganese, zinc, and copper were most commonly detected in significant amounts; but concentrations of the other metals such as lead, arsenic, and boron were low. In a few cases, aluminum, molybdenum, nickel, and antimony were found to be present in high concentrations in streams draining mining operations. Turbidities greater than 12 JTU were obtained from only 5% of the samples tested. In 86% of the samples so tested, turbidities ranged from zero to 7 JTU. Suspended sediment concentrations were less than 20 mg/l in 80% of the samples and a median suspended sediment of 4.5 mg/l was obtained for the Stillwater mainstem and Iron Creek in contrast to median values near 25 mg/l and 58 mg/l for the Middle and Lower Yellowstone River

Table 12

Typical Chemical Analyses of Water in the Stillwater River Sub-basin (43C)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Stillwater River Mainstem																																		
nr headwaters	WQB	8/12/69	---	---	7.2	---	---	245	---	---	---	---	30.0	4.3	93	---	---	---	---	38	64	2.5	0.2	0.001	0.08	---	---	---	0.10	---	---	---	0.04	---
nr headwaters	WQB	8/13/69	5.0	12	4.0	---	---	115	---	---	---	---	60	36	300	---	---	---	---	0.0	380	5.0	0.4	0.003	0.33	25	2.75	---	11.25	---	---	---	0.6	---
nr headwaters	WQB	8/13/69	7.0	6.0	7.5	---	---	19	---	8.0	---	---	25	7.8	95	---	---	---	---	55	44	2.5	0.2	1.5	0.07	1.5	0.53	---	0.7	---	---	---	0.04	---
nr headwaters	WQB	9/3/69	---	---	7.5	---	---	18	---	---	---	---	27	9.0	105	---	---	---	---	60	55	2.5	0.27	0.0	0.07	---	---	---	0.25	---	---	---	0.10	---
nr headwaters	SRT	8/24/71	12.0	0.33	7.73	290	---	---	---	---	---	---	44	5.3	130	1.4	0.8	0.1	49	40	95	1.6	0.0	0.5	0.05T	0.003	0.080	---	---	---	0.002	---	0.005	0.010
nr headwaters	SRT	8/24/71	13.0	0.40	4.20	480	---	---	---	---	---	---	47	9.8	156	1.3	1.0	0.0	0.0	0.0	234	0.7	0.11	1.6	0.05T	0.009	1.38	---	---	0.10	0.002	---	0.005	0.010
nr headwaters	SRT	8/24/71	20.0	0.10	2.50	2266	---	---	---	---	---	---	18.5	33.0	182	2.4	1.8	0.1	0.0	0.0	1283	6.0	0.0	16.5	---	0.096	10.00	---	---	0.10	0.002	---	---	0.010
nr headwaters	SRT	8/24/71	13.0	0.50	3.04	928	---	---	---	---	---	---	27	15.1	130	1.6	1.2	0.1	0.0	0.0	454	0.9	0.0	1.7	0.05T	0.003	2.87	---	---	0.10	0.002	---	0.005	0.010
nr headwaters	SRT	8/24/71	16.0	5.6	7.95	168	---	---	---	---	---	---	21	5.5	74	1.7	0.4	0.1	54	44	34	0.1	0.0	0.1	0.05T	0.0	0.16	---	---	---	0.002	---	0.005	0.010
near Woodbine Campground	WQB	11/4/69	3.5	---	7.2	---	---	0.37	---	10.0	---	---	8.0	3.6	35	---	---	---	---	33	5	5.0	0.11	0.006	0.08	0.02	0.0	---	0.01	---	---	---	0.03	---
near Woodbine Campground	WQB	12/9/69	0.0	---	7.6	---	34	0	---	---	---	---	24	5	80	0.0*	---	---	28	---	23	9	0.0	0.0	0.01T	0.10	---	0.0	0.0	---	---	---	---	---
near Woodbine Campground	WQB	6/8/70	8.0	---	6.65	---	30	0	---	---	---	---	4	7	40	0.0*	---	---	30	---	0.4	0.0	0.1	0.2	0.03T	0.10	---	0.03	0.0	0.0	0.0	---	---	---
near Woodbine Campground	WQB	6/8/70	7.0	---	5.75	---	30	0	---	---	---	---	4	7	40	0.0*	---	---	24	---	3	0.0	0.1	0.1	0.04T	0.0	---	0.01	0.0	0.0	0.0	---	---	---
near Woodbine Campground	WQB	7/13/70	10.0	---	7.2	---	40	---	---	---	---	---	12	7	60	0.0*	---	---	70	---	0.0	0.0	0.1	0.0	0.02T	0.2	---	0.0	<.01	---	0.0	---	---	---
near Woodbine Campground	WQB	8/12/70	15.0	---	7.6	---	40	---	---	---	---	---	4	7	40	0.0*	---	---	43	---	0.0	0.0	0.1	0.0	0.0T	3.04	---	0.0	0.03	---	0.0	---	---	---
near Woodbine Campground	WQB	10/14/70	---	---	---	---	40	---	---	---	---	---	12	15	90	0.0*	---	---	40	---	6	0.0	0.1	0.2	<.001T	0.0	---	0.08	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	10/14/70	---	---	---	---	30	---	---	---	---	---	8	12	70	0.0*	---	---	30	---	2	0.0	0.0	0.2	0.0T	0.0	---	0.06	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	12/8/70	---	---	---	---	40	---	---	---	---	---	8	15	80	0.0*	---	---	40	---	9	0.0	0.0	0.3	0.03T	0.0	---	0.07	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	1/19/71	0.0	---	7.2	---	60	0	---	---	---	---	16	15	100	0.0*	---	---	60	---	10	0.0	0.1	0.5	0.02	0.1	---	0.03	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	2/22/71	2.0	---	7.9	---	70	0	---	---	---	---	16	7	70	4.0*	---	---	49	---	0.0	3.0	0.2	0.3	0.04T	0.0	---	0.07	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	2/22/71	0.0	---	8.0	---	34	0	---	---	---	---	12	0.0	30	2.0*	---	---	61	---	0.0	0.0	0.2	0.4	0.02T	0.0	---	0.07	0.0	---	0.0	---	---	---
near Woodbine Campground	WQB	3/16/71	3.0	---	8.1	---	70	0	---	---	---	---	24	2	70	1.7*	---	---	73	---	19	0.0	0.3	0.38	0.03T	0.0	---	0.05	0.0	---	0.0	---	---	---
near Woodbine Campground	AC	3/23/71	0.0	50E	6.8	---	99	0	---	---	---	---	4.8	1.0	16	2.0	---	---	37	30	51	2.0	0.10	1.0	---	0.04	0.018	0.01	0.01	0.01	---	---	<.005	<.001
near Woodbine Campground	AC	6/23/71	5.6	---	6.9	---	40	5	---	---	---	---	4.0	1.0	14	0.7	---	---	21	18	11.9	0.0	0.05	0.22	---	0.050	0.025	0.019	0.022	0.006	0.009	---	0.01	<.005
near Woodbine Campground	AC	8/24/71	15.1	---	7.6	---	31	0.4	---	---	---	---	4.4	0.9	15	1.0	0.6	---	17	14	4.4	2.3	0.0	0.14	---	0.0	0.0	0.003	0.005	<.01	0.006	---	<.005	<.005
near Woodbine Campground	AC	11/2/71	0.0	---	7.9	---	35	0.3	---	---	---	---	5.4	1.6	20	0.9	0.7	---	24	20	1.6	1.3	0.08	0.02	0.0	<.05	0.0	<.005	<.005	<.01	0.003	---	<.010	<.005
near Woodbine Campground	SRT	2/19/71	0.3	---	7.8	57	---	---	---	---	---	---	6.0	0.6	17	2.1	0.8	0.2	24	20	5	0.1	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	0.010
near Woodbine Campground	SRT	6/9/71	3.9	550	6.7	33	---	---	---	---	---	---	5.3	0.6	16	1.0	0.9	0.1	17	14	4	2	0.10	0.0	---	0.0	0.010	0.010	---	---	---	---	---	---
near Woodbine Campground	SRT	7/26/71	12.9	400	6.9	31	---	---	---	---	---	---	3.3	1.1	13	1.1	0.7	0.1	13	10	3	0.4	0.0	0.2	---	0.0	0.0	0.010	---	---	---	---	---	---
near Woodbine Campground	SRT	11/17/71	0.6	89	7.3	50	---	---	---	---	---	---	5.9	1.4	20	1.9	0.9	0.2	20	16	7	1.0	0.0	0.6	0.05T	0.0	0.0	0.010	0.010	---	---	---	0.005	0.010
near Woodbine Campground	SRT	2/14/71	0.0	---	6.6	54	---	0	---	---	---	---	6.0	1.2	20	1.9	0.9	0.2	23	19	6	0.5	0.0	0.7	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Woodbine Campground	SRT	4/12/71	6.2	70	7.2	114	---	---	---	---	---	---	11.4	2.8	40	2.2	1.5	0.2	40	32	4	1.0	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near Woodbine Campground	SRT	6/9/71	3.9	575	6.5	35	---	---	---	---	---	---	5.1	0.8	16	2.7	0.9	0.1	13	10	3	1.0	0.1	0.0	---	0.0	0.0	0.010	---	---	---	---	---	---
near Woodbine Campground	SRT	7/26/71	8.2	425	6.8	34	---	---	---	---	---	---	4.0	1.0	14	1.1	0.7	0.1	14	12	4	0.5	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near Woodbine Campground	SRT	10/19/71	3.4	500	7.1	69	---	---	---	---	---	---	7.5	2.5	29	1.8	0.9	0.1	27	22	11	0.5	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Woodbine Campground	SRT	1/22/72	0.6	---	7.5	92	---	0	---	---	---	---	12.0	1.9	38	1.9	0.9	0.1	35	29	14	0.5	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Woodbine Campground	FG	Mean	0.0	---	7.8	---	23	0	---	9.5	---	---	2.6	0.6	11	0.6	0.4	---	13	10	2.0	0.2	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
near Woodbine Campground	FG	Mean	5.0	---	8.3	---	37	2	---	11.4	---	---	4.9	1.1	17	1.4	0.7	---	19	15	4.5	0.5	0.0	0.3	---	0.06	0.0	<.01	<.01	---	---	---	---	<.01
near Woodbine Campground	FG	Maximum	12.9	---	8.4	---	49	10	---	16.0	---	---	7.1	1.8	21	2.5	1.6	---	26	22	7.4	1.5	0.1	1.0	---	0.20	0.01	0.01	0.01	---	---	---	---	<.01
near Woodbine Campground	FG	Minimum	0.0	---	7.0	---	27	0	---	9.4	---	---	3.6	0.7	12	0.6	0.4	---	13	10	2.8	0.0	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
near Woodbine Campground	FG	Mean	6.2	---	8.2	---	54	2	---	10.9	---	---	8.4	2.0	28	1.6	0.8	---	28	23	8.3	0.5	0.0	0.3	---	0.06	0.0	<.01	<.01	---	---	---	---	<.01
near Woodbine Campground	FG	Maximum	13.4	---	8.5	---	92	8	---	13.4	---	---	16.4	3.1	51	2.7	1.5	---	51	42	14.0	1.4	0.1	1.0	---	0.24	0.01	0.02	0.02	---	---	---	---	<.01
near Nye	WQB	6/8/70	9.0	---	7.5	---	70	0	---	---	---	---	16	2	50	7*	---	---	70	---	4	0.0	0.1	0.1	0.04T	1.6	---	0.11	0.0	0.0	0.002	---	---	---
near Nye	AC	3/23/71	0.0	50E	7.30	---	111	0	---	---	---	---	12.8	5.8	56	3.4	---	---	67	55	21	0.0	0.15	1.48	---	0.08	0.004	0.004	0.002	0.008	---	---	<.005	<.001
near Nye	AC	6/22/71	10.6	---	7.5	---	31	10	---	---	---	---	4.8	2.8	24	0.8	---	---	21	17	1.6	0.0	0.14	0.16	---	0.32	0.005	0.052	0.014	0.003	0.002	---	<.01	<.005
near Nye	AC	8/27/71	---	---	7.93	---	61	0.35	---	---	---	---	8.6	2.2	30	1.7	0.6	---	34	28	11.4	2.3	0.026	0.16	---	0.044	0.002	0.013	0.009	0.04	0.004	---	0.005	<.005
near Nye	AC	11/2/71	0.0	---	7.8	---	71	0.30	---	---	---	---	10.1	3.6	40	1.4	0.8	---	44	36	9.9	1.4	0.08	0.04	0.0	<.05	0.0	<.005	<.005	<.010	0.002	---	<.010	<.005
near Nye	SRT	6/25/71	8.0	2000	7.1	34	---	---	---	---	---	---	4.0	0.9	13	1.1	0.9	0.1	14	12	3	0.4	0.0	0.5	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near Nye	SRT	8/4/71	12.0	746	7.0	49	---	---	---	---	---	---	3.7	1.6	16	1.6	1.1	0.2	20	16	4	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
near Nye	SRT	11/18/71	2.2	87	7.7	112	---	---	---	---	---	---	12.1	4.8	50	2.4	1.1	0.1	47	38	14	1.0	0.0	0.4	0.05T	0.0	0.0	0.010	0.010	---	---	---	0.005	0.010
near Nye	SRT	6/22/71	10.6	---	7.1	---	18	---	---	---	---	---	4.8	1.4	31	0.8	---	---	21	17	2	0.0	0.13	0.2	---	0.0	0.005	0.052	0.014	0.003	0.002	---	0.010	0.005
near Nye	SRT	11/2/71	0.0	---	8.0	---	---	0	---	---	---	---	10.1	3.6	---	1.4	0.8	---	44	---	10	1.0	0.08	0.04	0.0T	0.0	0.0	0.005	0.005	0.010	0.002	---	0.010	0.005
near Beehive	WQB	8/12/70	15.0	---	7.9	---	60	---	---	---	---	---	20	7	80	0.0*	---	---	70	---	7	0.0	0.2	0.0	0.0	0.0	---	0.0	0.03	---	0.0	---	---	---
near Beehive	USGS	10/5/70	12.0	234	8.1	166	94	0	2	9.2	---	---	20	6.3	76	3.3	1.0	0.2	73	62	19	1.2	0.2	---	---	0.0	0.0	---	0.017	0.0	---	0.0	0.0	---
near Beehive	USGS	1/12/71	0.0	99	7.5	196	120	0	2	11.0	---	---	22	7.9	88	3.9	0.9	0.2	93	74	23	0.6	0.2	0.10	0.03	0.11	0.0	0.010	0.021	0.0	0.0	0.02	0.001	0
near Beehive	USGS	4/12/71	3.5	83	7.9	186	112	0	1	8.8	---	---	23	8.0	90	3.7	1.2	0.2	84	---	22	1.2	0.1	0.20	0.03	0.03	0.0	0.030	0.004	0.005	0.0	0.02	0.001	0.001
near Beehive	USGS	6/10/71	8.5	3350	8.0	57	40	1	146	9.6	---	---	7.4	2.2	28	1.0	0.3	0.1	33	---	7.0	0.3	0.0	0.06	0.0	0.07	0.0	---	---	---	---	---	---	---
near Beehive	USGS	7/8/71	6.0	2060	7.2	61	36	0	13	8.8	---	---	6.8	2.3	26	1.0	0.6	0.1	29	40	4.5	1.3	0.1	0.02	0.03	0.02	0.054	---	---	---	---	---	---	---
near Beehive	USGS	9/8/71	8.0	522	8.0	106	63	0	2	8.8	---	---	12	3.9	46	2.2	0.8	0.1	54	46	8.3	1.0	0.5	0.22	0.0	0.02	0.0	---	---	---	---	---	---	---
near Beehive	USGS	1/12/72	0.0	128	8.0	200	123	0	4	12.0	---	---	28	8.2	100	3.9	1.5	0.2	97	81	22	1.6	0.1	0.16	0.0	0.01	0.01	0.020	0.003	0.004	0.002	0.02	0.002	0.001
near Beehive	USGS	5/23/72	8.5	1080	6.9	80	51	1	5	9.8	---	---	10	2.9	37	1.0	0.5	0.1	40	33	8.7	1.1	0.1	0.04	0.03	0.03	0.0	---	---	---	---	---	---	---
near Beehive	USGS	6/5/72	9.0	3640	7.5	50	---	1	26	10.0	---	---	---	1.6	---	---	---	---	---	19	---	---	---	---	---	0.05	0.0	0.020	0.013	0.003	0.0	0.01	0.0	0.0
near Beehive	USGS	7/17/72	8.5	1330	7.7	70	40	0	4	9.8	---	---	7.7	2.4	29	1.1	0.4	0.1	31	26	5.8	1.0	0.4	0.21	0.0	0.02	0.021	0.0	0.004	0.002	0.001	0.01	0.0	0.0
near Beehive	USGS	9/11/72	8.0	724	7.7	80	53	1	2	9.4	---	---	9.9	3.2	38	1.8	0.5	0.1	41	34	9.4	1.8	0.1	0.07	0.0	0.02	0.0	---	---	---	---	---	---	---
near Beehive	USGS	1/10/72	0.0	104	---	200	112	1	1	12.1	---	---	22	7.1	84	3.8	1.0	0.2	91	---	21	1.4	0.2	0.12	0.01	0.009	0.02	0.010	0.010	0.0	0.003	0.01	0.0	0.001
near Beehive	USGS	4/9/73	3.5	106	8.0	220	132	1	6	11.1	---	---	28	9.0	110	4.7	1.1	0.2	107	89	26	0.8	0.2	0.07	0.01	0.05	0.0	0.020	0.007	0.003	0.002	0.03	0.0	0.0
near Beehive	USGS	6/13/73	6.0	3050	6.8	58	33	1	44	11.0	---	---	6.0	1.6	22	1.3	0.4	0.1	26	21	5.6	0.5	0.0	0.04	0.0	0.04	0.0	0.010	0.010	0.002	0.0	0.0	0.0	0.001
near Beehive	USGS	7/19/73	10.5	773	6.8	95	54	0	3	9.4	---	---	9.7	3.3	38	3.8	1.0	0.3	41	31	9.0	0.8	0.0	0.04	0.0	0.05	0.01	---	---	---	---	---	---	---
near Beehive	USGS	9/18/73	7.0	335	7.2	158	90	---	4	10.8	---	---	17	5.4	65	4.8	1.7	0.3	75	58	16	1.2	0.1	0.0	0.03	0.08	0.0	---	---	---	---	---	---	---
near Beehive	AC	9/1/71	11.2	---	7.1	---	91	0.49	---	---	---	---	15.2	3.9	54	2.3	---	---	59	48	8.6	1.9	0.042	0.66	---	0.0	0.0	0.006	0.020	<.005	---	---	<.002	<.005
near Beehive	AC	11/2/71	2.2	---	8.35	270	131	0.27	---	---	---	---	18.4	7.3	76	1.9	0.8	---	75	72	21	2.3	0.16	0.4	---	<.05	0.0	0.005	<.005	<.010	0.0	---	<.010	<.005
at Midnight Canyon Bridge	WQB	6/8/70	8.0	---	7.50	---	50	0	---	---	---	---	10	6	50	0.0*	---	---	40	---	4	0.0	0.1	0.2	0.04T	0.70	---	0.08	0.0	0.0	0.0	---	---	---
at Midnight Canyon Bridge	WQB	7/13/70	10.5	---	7.3	---	40	---	---	---	---	---	8	7	50	0.0*	---	---	50	---	2	0.0	0.1	0.0	0.005T	0.0	---	0.0	0.0	---	0.0	---	---	---
at Midnight Canyon Bridge	WQB	8/12/70	15.0	---	8.0	---	60	---	---	---	---	---	20	12	100	0.6*	---	---	85	---	7	0.0	0.2	0.0	0.0T	0.1	---	0.0	0.03	---	0.0	---	---	---
at Midnight Canyon Bridge	WQB	10/14/70	---	---	---	---	90	---	---	---	---	---	20	22	140	0.0*	---	---	90	---	17	0.0	0.1	0.3	0.0T	0.0	---	0.06	0.06	---	0.0	---	---	---
at Midnight Canyon Bridge	WQB	1/9/71	0.0	---	7.4	---	110	0	---	---	---	---	28	24	170	0.0*	---	---	100	---	19	0.0	0.2	0.1	0.005	0.0	---	0.02	0.0	---	0.0	---	---	---
at Midnight Canyon Bridge	WQB	3/16/71	3.5	---	7.9	---	110	0	---	---	---	---	36	5	110	3.4*	---	---	110	---	25	0.0	0.1	0.28	0.05T	0.0	---	0.02	0.0	---	0.0	---	---	---
at A. Johnson Bridge	WQB	12/9/69	0.0	---	7.82	---	130	5	---	---	---	---	40	15	160	0.0*	---	---	71	---	27	10	0.04	0.80	0.36T	0.0	---	0.0	0.0	---	---	---	---	---
at A. Johnson Bridge	WQB	6/8/70	9.0	---	7.45	---	50	0	---	---	---	---	10	11	70	0.0*	---	---	40	---	5	0.5	0.1	0.1	0.07T	1.1	---	0.06	0.0	0.	0.002	---	---	---
at A. Johnson Bridge	WQB	7/12/70	11.0	---	7.6	---	50	---	---	---	---	---	12	5	50	0.0*	---	---	60	---	1	0.0	0.2	0.0	0.05T	0.1	---	0.0	<.01	---	<.001	---	---	---
at A. Johnson Bridge	WQB	8/12/70	16.0	---	8.8	---	90	---	---	---	---	---	28	12	120	0.0*	---	---	100	---	10	0.0	0.2	0.0	0.0T	0.0	---	0.0	0.03	---	0.0	---	---	---
at A. Johnson Bridge	WQB	10/14/70	---	---	---	---	110	---	---	---	---	---	24	24	160	0.0*	---	---	110	---	16	0.0	0.1	0.3	0.031	0.0	---	0.04	0.0	---	0.0	---	---	---
at A. Johnson Bridge	WQB	11/10/70	---	---	---	---	130	---	---	---	---	---	32	20	160	0.0*	---	---	120	---	27	0.0	0.3	0.2	0.005T	0.0	---	0.07	0.0	---	0.0	---	---	---
at A. Johnson Bridge	WQB	12/8/70	---	---	---	---	130	---	---	---	---	---	32	20	160	0.0*	---	---	120	---	18	0.0	0.1	0.2	0.03T	0.0	---	0.05	0.0	---	0.05	---	---	---
at A. Johnson Bridge	WQB	1/19/71	0.0	---	7.4	---	130	0	---	---	---	---	28	29	190	0.0*	---	---	120	---	21	0.0	0.6	0.8	0.04	0.08	---	0.02	0.0	---	0.0	---	---	---
at A. Johnson Bridge	WQB	2/22/71	1.0	---	7.9	---	150	0	---	---	---	---	40	10	140	7.0*	---	---	140	---	19	0.0	0.3	1.0	0.02	0.0	---	0.05	0.0	---	0.0	---	---	---
at A. Johnson Bridge	WQB	3/16/71	3.0	---	7.9	---	140	0	---	---	---	---	44	7	150	5.5*	---	---	140	---	29	0.0	0.33	0.05	0.03T	0.0	---	0.06	0.0	---	0.0	---	---	---

Table 12
(Continued)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
near Columbus	WQB	12/9/69	0.0	---	7.74	---	90	5	---	---	---	---	28	22	160	0.0*	---	---	57	---	20	9	0.02	0.0	0.2T	0.08	---	0.0	0.0	---	---	---	---	---
near Columbus	WQB	6/8/70	9.0	---	7.45	---	60	0	---	---	---	---	12	12	80	0.0*	---	---	60	---	6	0.5	0.1	0.2	0.09T	1.6	---	0.02	0.0	0.0	0.0	---	---	---
near Columbus	WQB	7/13/70	12.5	---	7.8	---	60	---	---	---	---	---	20	7	80	0.0*	---	---	90	---	0.0	0.0	0.15	0.0	0.09T	0.0	---	0.0	<.01	---	<.001	---	---	---
near Columbus	WQB	8/12/70	16.0	---	8.2	---	70	---	---	---	---	---	20	10	90	0.0*	---	---	90	---	5	0.0	0.2	0.0	0.0T	0.0	---	0.0	0.03	---	0.0	---	---	---
near Columbus	WQB	10/14/70	---	---	---	---	100	---	---	---	---	---	24	20	140	---	---	---	110	---	10	0.0	0.1	0.1	<.001T	0.1	---	0.04	0.0	---	0.0	---	---	---
near Columbus	WQB	11/10/70	---	---	---	---	100	---	---	---	---	---	24	17	130	0.0*	---	---	110	---	14	0.0	0.3	0.0	0.01T	0.0	---	0.05	0.0	---	0.0	---	---	---
near Columbus	WQB	12/8/70	---	---	---	---	110	---	---	---	---	---	28	22	160	0.0*	---	---	110	---	11	0.0	0.2	0.3	0.03T	0.0	---	0.05	0.0	---	0.0	---	---	---
near Columbus	WQB	1/19/71	0.0	---	7.4	---	110	0	---	---	---	---	24	22	150	0.0*	---	---	100	---	13	0.0	0.1	0.0	0.03	0.06	---	0.04	0.0	---	0.0	---	---	---
near Columbus	WQB	2/22/71	0.5	---	7.9	---	110	8	---	---	---	---	28	7	100	7.0*	---	---	110	---	1.0	0.0	0.2	0.7	0.07T	0.0	---	0.04	0.0	---	0.0	---	---	---
near Columbus	WQB	3/16/71	1.0	---	8.2	---	100	---	---	---	---	---	36	2	110	6.3*	---	---	110	---	18	0.0	0.3	0.14	0.04T	0.08	---	0.03	0.0	---	0.0	---	---	---
near Columbus	WQB	10/2/74	---	498	7.69	174	142	---	---	10.3	---	---	22	4.4	74	6.3	---	0.3	95	78	13.5	0.3	---	0.04	0.21	0.26	0.09	<.01	<.01	<.01	<.001	<.10	<.01	<.001
Stillwater River Tributaries near Nye																																		
Goose Creek:																																		
above Goose Lake	SRT	7/29/71	---	5	6.1	15	---	---	---	---	---	---	1.0	0.3	4	0.6	0.6	0.1	3	2	2	0.2	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
above Goose Lake	SRT	8/26/71	14.0	5	6.9	31	---	---	---	---	---	---	1.8	0.7	7	0.8	0.5	0.1	6	5	2	0.3	0.0	0.0	0.05T	0.0	0.0	0.010	---	---	0.002	---	---	0.010
at mouth	SRT	8/25/71	11.0	25.5	6.92	22	---	---	---	---	---	---	1.5	0.6	6	0.7	0.4	0.1	7	6	1.2	0.3	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Unnamed Creek	AC	3/23/71	0.0	0.07	6.9	---	74	0	---	---	---	---	9.6	1.9	32	4.1	---	---	49	40	7.8	1.0	0.12	0.70	---	0.001	0.019	0.012	0.005	0.008	---	---	<.005	0.001
Unnamed Creek	AC	6/23/71	5.6	3.2	7.53	---	41	2	---	---	---	---	7.2	1.9	26	1.9	---	---	29	24	0.0	0.0	0.10	0.10	---	0.07	0.003	0.023	0.004	0.01	0.002	---	0.01	<.005
Unnamed Creek	AC	8/27/71	12.3	1.5	7.32	---	63	0.3	---	---	---	---	11.2	0.7	30	2.6	---	---	41	34	4.0	1.9	0.08	0.10	---	0.096	0.0	0.002	0.008	0.01	0.020	---	<.005	<.005
Unnamed Creek	AC	11/2/71	1.7	0.14	8.03	---	65	0.19	---	---	---	---	9.9	2.1	33	1.6	1.3	---	44	36	4.1	1.5	0.09	0.0	---	<.05	0.0	<.005	<.005	<.01	0.0	---	<.01	<.005
Woodbine Creek	FG	Minimum	5.6	---	7.5	---	20	0	---	10.4	---	---	2.6	0.5	10	1.0	0.5	---	11	9	2.9	0.1	0.0	0.1	---	0.0	0.0	---	---	---	---	---	---	---
Woodbine Creek	FG	Maximum	6.2	---	8.4	---	26	8	---	10.6	---	---	3.1	1.1	11	1.2	0.6	---	11	9	3.0	0.2	0.0	0.3	---	0.05	0.0	<.01	<.02	---	---	---	---	<.01
Verdigris Creek:																																		
near headwaters	SRT	6/23/71	6.7	9	7.1	---	20	---	---	---	---	---	3.4	2.7	30	1.4	---	---	18	15	5	0.0	0.0	0.1	---	0.0	0.007	0.022	0.007	0.004	0.003	---	0.010	0.005
near headwaters	SRT	8/25/71	8.4	1	7.4	---	34	---	---	---	---	---	6.5	4.4	60	2.0	0.6	---	42	35	2	2.0	0.0	0.1	---	0.0	0.0	0.005	0.005	0.010	0.004	---	0.005	0.005
near headwaters	FT	8/25/71	13.4	---	7.7	---	66	---	---	---	---	---	8.9	10.6	89	2.5	0.6	---	39	32	23	2.8	0.13	0.22	---	0.001	0.052	0.016	0.089	0.040	0.005	---	0.005	0.005
near mouth	WQB	11/3/69	---	<.05	7.4	---	---	13	---	---	---	---	12.0	16.2	98	---	---	---	---	43	63	6.3	---	0.014	0.03	0.23	---	---	0.04	---	---	---	0.025	---
near mouth	WQB	2/24/70	---	<.05	7.4	---	---	22	---	---	---	---	12.0	19.2	110	---	---	---	---	40	76	5.0	---	0.002	---	0.58	0.2	---	0.12	---	---	---	0.02	---
near mouth	WQB	8/5/70	---	---	---	---	90	---	---	---	---	---	12.0	10.0	70	2.0*	---	---	60	---	30	0.0	0.2	0.1	---	0.08	---	---	---	---	---	---	---	---
near mouth	SRT	3/23/71	0.0	150	7.0	---	93	---	---	---	---	---	9.6	13.6	147	3.1	---	---	49	40	65	0.0	0.18	0.4	0.19T	0.0	0.015	0.010	0.010	0.007	---	---	0.005	0.001
near mouth	SRT	6/23/71	10.1	14	7.2	---	23	---	---	---	---	---	4.2	3.1	37	1.3	---	---	18	15	---	0.0	0.08	0.1	---	0.0	0.017	0.018	0.107	0.007	0.001	---	0.005	0.005
near mouth	SRT	6/24/71	12.0	10	7.3	49	---	---	---	---	---	---	5.6	1.6	20	1.8	0.9	0.2	15	---	---	0.4	0.0	0.0	0.05T	0.0	0.010	---	---	---	0.002	---	0.005	0.010
near mouth	SRT	8/5/71	12.0	0.4	7.4	124	---	---	---	---	---	---	7.5	7.7	51	2.9	1.5	0.2	31	---	26	1.0	0.0	0.0	---	0.0	0.010	0.010	---	---	0.002	---	0.005	---
near mouth	SRT	8/25/71	15.7	1.0	7.5	---	64	---	---	---	---	---	9.5	9.7	102	2.4	0.6	---	37	30	40	2	0.09	0.1	---	0.0	0.018	0.015	0.032	0.020	0.005	---	0.005	0.005
near mouth	SRT	11/2/71	1.1	3	7.9	---	---	0	---	---	---	---	9.6	13.0	---	1.5	0.8	---	46	---	50	2	0.10	0.0	0.0T	0.0	0.0	0.005	---	0.010	0.0	---	0.010	0.005
near mouth	SRT	11/17/71	0.0	1.0	7.7	174	---	---	---	---	---	---	10.6	12.6	79	2.6	1.0	0.1	40	---	50	0.5	0.0	0.7	0.05T	0.0	0.060	---	0.052	---	---	---	0.005	0.010
near mouth	FG	Minimum	0.0	---	7.7	---	50	0	---	8.5	---	---	3.4	4.3	26	1.5	0.5	---	21	18	7.2	0.1	0.0	0.0	---	0.17	0.01	<.01	0.05	---	---	---	---	<.01
near mouth	FG	Mean	9.0	---	8.2	---	113	4	---	9.6	---	---	7.9	10.9	65	2.3	0.8	---	38	31	37	1.1	0.0	0.5	---	0.30	0.04	<.01	0.10	---	---	---	---	<.01
near mouth	FG	Maximum	15.1	---	8.5	---	150	10	---	10.7	---	---	11.3	16.0	93	3.0	1.1	---	48	39	61	3.3	0.0	1.0	---	0.58	0.06	0.015	0.14	---	---	---	---	<.01
near mouth	FG	Minimum	2.8	---	7.5	---	46	0	---	8.9	---	---	2.3	2.7	20	1.4	0.4	---	25	20	2.4	0.0	0.0	0.0	---	0.0	0.0	<.01	<.02	---	---	---	---	<.01
near mouth	FG	Mean	5.0	---	8.1	---	60	0	---	9.8	---	---	4.5	4.5	30	1.8	0.6	---	35	29	3.4	0.2	0.0	1.0	---	0.05	0.0	<.01	<.02	---	---	---	---	<.01
near mouth	FG	Maximum	8.4	---	8.5	---	76	0	---	10.4	---	---	6.6	5.6	37	2.0	0.7	---	42	34	4.4	0.4	0.0	2.4	---	0.10	0.0	0.01	<.02	---	---	---	---	<.01
Mountain View Creek:																																		
lake outlet	SRT	6/23/71	8.4	4	8.1	---	81	---	---	---	---	---	15.7	10.2	134	3.1	---	---	95	78	9	0.0	0.05	0.4	0.05T	0.0	0.012	0.020	0.010	0.020	0.002	---	0.030	0.035
lake outlet	SRT	8/18/71	16.8	1	7.9	---	63	---	---	---	---	---	14.4	6.6	110	4.0	1.0	---	76	62	7	0.3	0.09	0.3	0.05T	0.0	0.005	0.007	0.002	0.010	0.004	---	0.005	0.005
lake outlet	SRT	11/3/71	0.0	15	8.4	---	76	---	---	---	---	---	16.8	8.3	127	2.1	0.7	---	87	---	3	2.0	0.12	1.0	---	0.0	0.0	0.005	0.005	0.010	0.004	---	0.010	0.005
near mouth	WQB	8/5/70	---	---	---	---	120	---	---	---	---	---	24	22	---	3*	---	---	140	---	8	0.0	0.2	0.2	---	0.0	---	---	---	---	---	---	---	---
near mouth	SRT	6/22/71	8.4	5	7.7	---	64	---	---	---	---	---	15.0	6.6	101	2.7	---	---	---	142	7	0	0.05	0.1	---	0.0	0.004	0.016	0.004	0.016	0.001	---	0.020	0.005
near mouth	SRT	8/18/71	12.3	1	8.4	---	118	---	---	---	---	---	18.0	17.5	192	4.1	1.1	---	134	128	10	2	0.08	2.0	---	0.0	0.0	0.009	0.010	0.010	0.003	---	0.010	0.005
near mouth	SRT	11/3/71	0.0	1	8.5	---	117	---	---	---	---	---	16.8	18.0	184	2.1	1.0	---	125	120	7	4	0.05	2.2	---	0.0	0.0	0.005	0.015	0.010	0.001	---	0.014	0.005
near mouth	FG	Minimum	2.2	---	8.5	---	157	0	---	9.0	---	---	15.0	12.2	88	2.9	0.7	---	102	84	7.2	0.0	0.0	0.3	---	0.16	0.0	0.01	<.01	---	---	---	---	<.01
near mouth	FG	Maximum	11.2	---	8.5	---	209	10	---	11.2	---	---	17.4	17.9	118	4.0	0.7	---	136	112	11.0	2.0	0.0	2.2	---	0.21	0.0	0.01	<.01	---	---	---	---	<.01
Nye Creek:																																		
near headwaters	SRT	6/23/71	5.6	5	7.9	---	54	---	---	---	---	---	8.8	7.8	85	1.6	---	---	58	48	7	1.0	0.08	0.1	---	0.0	0.005	0.021	0.007	0.005	0.001	---	0.010	0.001
near headwaters	SRT	8/19/71	7.3	2	7.8	---	52	---	---	---	---	---	8.4	7.5	84	1.9	1.0	---	61	48	3	0.5	0.11	0.3	---	0.0	0.0	0.004	0.005	0.010	0.004	---	0.005	0.005
near headwaters	SRT	6/24/71	8.4	1	8.1	---	83	---	---	---	---	---	19.5	8.3	134	2.8	---	---	101	83	3	0.0	0.05	0.1	---	0.0	0.003	0.025	0.001	0.008	0.001	---	0.020	0.005
near headwaters	SRT	8/19/71	9.0	1	8.0	---	84	---	---	---	---	---	18.0	9.4	146	3.5	1.0	---	105	86	7	1.0	0.10	0.3	---	0.0	0.0	0.036	0.002	0.010	0.005	---	0.009	0.005
near headwaters	SRT	6/24/71	11.2	7	7.8	---	48	---	---	---	---	---	10.4	5.3	74	1.7	---	---	51	42	5	0.0	0.08	---	---	0.0	0.010	0.019	0.005	0.003	0.001	---	0.010	0.005
near headwaters	SRT	8/19/71	13.4	2	8.0	---	54	---	---	---	---	---	10.4	6.9	92	2.1	1.0	---	67	56	3	0.3	0.10	0.3	---	0.0	0.0	0.005	0.005	0.010	0.003	---	0.005	0.035
near headwaters	SRT	11/3/71	0.0	---	8.3	---	57	---	---	---	---	---	9.2	8.3	96	1.3	0.5	---	65	64	5	2.0	0.12	0.9	---	0.0	0.0	0.005	0.005	0.010	0.002	---	0.010	0.005
at mouth	SRT	6/24/71	9.0	9	7.7	89	---	---	---	---	---	---	9.6	4.6	43	2.3	0.9	0.2	49	40	3	0.3	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	---	0.010
at mouth	SRT	8/5/71	10.0	5	7.9	114	---	---	---	---	---	---	10.8	5.9	51	[illegible]	1.0	0.1	60	49	5	1.9	0.0	0.0	---	0.0	0.0	0.010	0.010	---	0.002	---	---	---
at mouth	SRT	11/17/71	0.0	2	7.9	119	---	---	---	---	---	---	11.7	6.4	56	2.3	0.6	0.1	66	54	6	0.5	0.0	0.3	0.05T	0.0	0.0	0.010	0.010	---	---	---	---	0.010
at mouth	FG	Minimum	0.0	---	8.1	---	86	0	---	8.2	---	---	11.2	3.7	44	1.5	0.4	---	54	44	2.0	0.0	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
at mouth	FG	Mean	5.6	---	8.3	---	104	2	---	10.6	---	---	14.3	4.5	55	1.9	0.5	---	67	55	4.8	0.2	0.0	0.4	---	0.05	0.0	0.01	<.01	---	---	---	---	<.01
at mouth	FG	Maximum	10.6	---	8.5	---	129	7	---	12.9	---	---	18.2	5.6	68	2.4	0.6	---	80	66	7.9	0.4	0.0	0.7	---	0.11	0.01	0.01	<.01	---	---	---	---	<.01
South Nye Creek	FG	Minimum	2.8	---	8.4	---	98	5	---	9.7	---	---	8.8	6.8	50	1.9	0.5	---	58	48	4.8	0.5	0.0	0.0	---	0.08	0.0	0.01	<.01	---	---	---	---	<.01
South Nye Creek	FG	Maximum	9.5	---	8.4	---	163	12	---	10.8	---	---	17.9	9.8	85	3.5	0.5	---	101	83	9.0	0.8	0.0	0.8	---	1.28	0.03	0.01	<.01	---	---	---	---	<.01
Silver Creek	WQB	8/5/70	---	---	---	---	220	---	---	---	---	---	56	12	190	2*	---	---	170	---	68	0.0	0.5	0.1	---	0.0	---	---	---	---	---	---	---	---
Silver Creek	FG	Minimum	10.1	---	8.6	---	301	0	---	8.6	---	---	49	17.8	195	1.9	0.6	---	143	121	74	0.1	0.0	0.2	---	0.03	0.0	0.01	<.01	---	---	---	---	<.01
Silver Creek	FG	Maximum	15.7	---	8.6	---	305	0	---	9.6	---	---	50	18.0	199	2.1	0.7	---	147	126	74	0.4	0.2	0.9	---	0.04	0.01	0.01	<.01	---	---	---	---	<.01
Little Rocky Creek:																																		
near Benbow Mine	SRT	6/24/71	3.9	14	7.1	---	16	---	---	---	---	---	6.7	0.0	29	1.1	---	---	18	15	2	1.0	0.06	0.1	---	0.0	0.003	0.012	0.003	0.004	0.003	---	0.010	0.005
near Benbow Mine	SPT	8/17/71	9.1	1	7.8	---	19	---	---	---	---	---	4.8	1.7	42	1.7	0.9	---	27	22	5	0.3	0.08	0.3	---	0.0	0.0	0.016	0.009	0.010	0.004	---	0.005	0.005
near Benbow Mine	SRT	6/23/71	5.5	21	7.4	40	---	---	---	---	---	---	4.3	2.0	19	1.5	0.7	0.1	17	14	4	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near Benbow Mine	SRT	8/19/74	---	---	7.7	69	---	---	---	---	---	---	2.8	4.5	26	1.4	0.5	0.2	37	30	1	0.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
at campground	SRT	6/23/71	6.8	65	7.7	73	---	---	---	---	---	---	10.8	1.8	34	1.8	0.8	0.1	39	32	2	0.5	0.0	0.5	---	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
at campground	SRT	8/19/71	---	---	7.7	102	---	---	---	---	---	---	10.0	3.9	41	1.3	0.5	0.1	56	46	2	0.2	0.0	0.0	---	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near mouth	SRT	3/23/71	0.0	1	8.0	---	163	---	---	---	---	---	40.0	15.5	302	---	---	---	183	150	62	1.0	0.10	[illegible]	---	0.0	0.012	0.011	0.009	0.013	---	---	0.005	0.001
near mouth	SRT	6/23/71	8.3	47	7.9	---	62	---	---	---	---	---	17.6	4.5	100	2.2	---	---	75	62	0.0	0.0	0.09	0.2	---	0.0	---	0.016	0.010	0.011	0.003	---	0.010	0.003
near mouth	SRT	8/24/71	15.1	0.4	8.1	---	246	---	---	---	---	---	69.0	18.3	432	13.5	0.6	---	254	246	72	2.0	0.33	0.9	---	0.0	0.029	0.010	---	---	0.005	---	---	---
near mouth	SRT	8/24/71	15.1	0.4	7.8	---	248	---	---	---	---	---	64.0	22.0	439	12.5	0.6	---	256	248	81	2.0	0.32	0.7	---	0.0	0.006	---	0.030	0.030	---	---	0.005	0.005
near mouth	SRT	11/2/71	1.1	13	8.5	---	---	0	---	---	---	---	35.0	12.1	---	3.7	1.0	---	128	---	32	3.0	0.20	0.4	---	0.0	0.0	0.005	0.005	0.011	0.001	---	0.010	0.005
near mouth	FG	Minimum	0.0	---	8.1	---	86	0	---	8.2	---	---	11.2	3.7	44	1.5	0.4	---	54	44	2.0	0.0	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
near mouth	FG	Mean	5.0	---	8.3	---	104	2	---	10.6	---	---	14.3	4.5	55	1.9	0.5	---	67	55	4.8	0.2	0.0	0.4	---	0.05	0.0	0.01	<.01	---	---	---	---	<.01
near mouth	FG	Maximum	12.3	---	8.5	---	129	7	---	12.9	---	---	18.2	5.6	68	2.4	0.6	---	80	66	7.9	0.4	0.0	0.7	---	0.11	0.01	0.01	<.01	---	---	---	---	<.01

Table 12
(Continued)

Sampling Site	Data Source	Date	T.	Q	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
West Fork of Stillwater River and Tributaries near Nye																																		
West Fork:																																		
above Cresent Creek	SRT	7/8/71	6.5	18	7.1	32	---	---	---	---	---	---	3.4	1.6	15	1.4	1.0	0.2	13	11	8	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
above Cresent Creek	AC	8/17/71	11.8	78E	7.68	---	35	0.33	---	---	---	---	4.8	1.0	16	1.1	1.0	---	22	18	5	0.0	0.08	0.30	---	0.0	0.0	0.014	0.004	<.01	0.004	---	<.005	<.005
above Cresent Creek	FC	Minimum	3.9	---	7.8	---	34	0	---	9.3	---	---	5.5	0.4	16	1.0	0.6	---	19	16	3.2	0.2	0.0	0.2	---	0.0	0.0	<.01	<.02	---	---	---	---	<.01
above Cresent Creek	FC	Mean	5.0	---	8.2	---	48	0	---	10.0	---	---	6.1	1.9	24	1.2	0.8	---	25	20	5.8	0.8	0.0	0.4	---	0.04	0.0	<.01	<.02	---	---	---	---	<.01
above Cresent Creek	FC	Maximum	6.2	---	8.5	---	55	2	---	10.5	---	---	7.1	2.8	28	1.4	0.9	---	30	24	8.6	2.0	0.0	0.7	---	0.10	0.0	0.01	<.02	---	---	---	---	<.01
near Forest Service boundary	WQB	11/3/69	1.5	---	7.3	---	---	0.2	---	10.0	---	---	8.0	3.6	35	---	---	---	---	38	3.0	3.8	0.17	0.038	0.08	0.02	0.0	---	0.03	---	---	---	0.03	---
near Forest Service boundary	AC	6/24/71	8.4	---	7.28	---	32	---	---	---	---	---	5.0	0.9	16	0.9	---	---	24	20	0.0	1.0	0.04	0.18	---	0.34	0.01	0.082	0.095	0.001	0.002	---	0.01	<.005
near Forest Service boundary	AC	8/18/71	11.2	111	8.20	---	48	0.23	---	---	---	---	6.8	1.7	24	1.2	1.0	---	34	28	1.8	0.3	0.09	0.30	---	0.06	0.0	0.019	0.021	<.01	0.001	---	<.005	<.005
near Forest Service boundary	AC	11/2/71	0.0	40	0.10	---	69	---	---	---	---	---	9.2	4.1	40	0.8	0.9	---	49	40	4.1	1.0	0.04	0.0	---	<.05	0.0	<.005	<.005	<.01	0.003	---	<.01	<.005
near Forest Service boundary	SRT	6/25/71	---	1120	7.1	33	---	---	---	---	---	---	4.7	1.0	16	1.5	1.3	0.2	15	13	0.4	0.4	---	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
near Forest Service boundary	SRT	8/5/71	---	158	7.2	53	---	---	---	---	---	---	3.9	2.0	18	1.4	1.1	0.1	26	21	3	1.0	---	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
near Forest Service boundary	SRT	8/20/71	---	159	7.1	45	---	---	---	---	---	---	3.1	1.6	14	1.2	0.9	0.1	21	18	0.4	0.3	---	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
near Forest Service boundary	SRT	11/19/71	1.1	30	7.7	97	---	---	---	---	---	---	11.1	4.1	44	1.8	1.1	0.1	50	41	7	0.5	---	0.6	0.05T	0.0	0.0	0.010	0.010	---	---	---	0.005	0.010
near mouth (Nye)	WQB	7/13/70	11.0	---	7.4	---	70	---	---	---	---	---	16	10	80	0.0*	---	---	70	---	3	0.0	0.2	0.0	0.005T	0.0	---	0.0	0.0	---	0.0	---	---	---
near mouth (Nye)	WQB	8/6/70	16.0	---	7.7	---	60	---	---	---	---	---	8.0	8.7	56	0.8*	---	---	49	---	4.1	0.0	0.0	0.04	---	0.1	---	---	0.01	0.0	0.0	---	---	---
near mouth (Nye)	WQB	10/14/70	---	---	---	---	140	---	---	---	---	---	36	24	190	---	---	---	140	---	24	0.0	0.2	0.3	0.0T	0.0	---	0.08	0.26	---	0.0	---	---	---
near mouth (Nye)	WQB	12/8/70	---	---	---	---	200	---	---	---	---	---	48	29	240	0.0*	---	---	180	---	39	0.0	0.2	0.5	0.03T	0.0	---	0.03	0.0	---	0.002	---	---	---
near mouth (Nye)	WQB	1/19/71	0.0	---	7.6	---	170	0	---	---	---	---	28	32	220	0.0*	---	---	160	---	30	0.0	0.3	0.1	0.01	0.08	---	0.09	0.0	---	0.0	---	---	---
near mouth (Nye)	WQB	3/16/71	3.6	---	8.2	---	70	0	---	---	---	---	48	12	160	3.2*	---	---	150	---	33	0.0	0.4	0.18	0.02T	0.0	---	0.04	0.0	---	0.0	---	---	---
near mouth (Nye)	AC	3/23/71	0.0	30	0.13	---	192	---	---	---	---	---	29	12.6	124	3.4	---	---	110	130	72	1.0	0.20	1.14	---	1.05	0.08	0.01	0.005	0.015	---	---	<.005	<.001
near mouth (Nye)	AC	6/23/71	6.7	---	7.2	---	54	22	---	---	---	---	9.4	3.2	36	1.2	---	---	39	32	0.9	0.0	0.08	0.12	---	0.71	0.03	0.073	0.01	0.007	0.001	---	0.015	<.005
near mouth (Nye)	AC	11/2/71	2.2	83	8.4	---	182	0.35	---	---	---	---	30	9.7	113	2.0	0.9	---	109	199	22	2.5	0.20	0.34	---	<.05	0.0	0.007	<.005	0.010	0.002	---	<.010	<.005
near mouth (Nye)	AC	8/25/71	14.6	---	7.8	---	148	---	---	---	---	---	25	7.3	92	2.8	0.6	---	100	82	9.6	2.3	0.19	0.12	---	0.0	0.002	0.013	0.008	0.015	0.003	---	<.005	<.005
near mouth (Nye)	SRT	2/9/71	0.6	---	7.5	152	---	---	---	---	---	---	18.2	5.5	68	2.1	0.9	0.1	84	69	7	0.2	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	0.010
near mouth (Nye)	SRT	4/13/71	5.6	16	7.0	182	---	---	---	---	---	---	19.5	6.7	76	2.4	1.8	0.1	94	77	3	1.0	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near mouth (Nye)	SRT	6/9/71	2.9	375	6.8	43	---	---	---	---	---	---	7.9	0.5	21	1.2	0.9	0.1	22	18	3	1.0	0.1	0.0	---	0.0	0.010	0.010	0.010	---	---	---	---	---
near mouth (Nye)	SRT	7/26/71	11.6	250	7.5	57	---	---	---	---	---	---	6.1	2.3	25	1.3	0.9	0.1	29	24	7	0.4	0.0	0.0	---	0.0	0.0	0.010	---	---	---	---	---	---
near mouth (Nye)	SRT	10/19/71	3.9	250	7.5	102	---	---	---	---	---	---	11.9	4.4	47	1.9	1.1	0.1	53	43	7	0.4	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.01
near mouth (Nye)	SRT	12/18/71	0.0	---	7.8	134	---	---	---	---	---	---	17.6	5.3	65	1.6	1.1	0.1	73	60	9	0.5	0.0	0.4	---	0.0	0.0	0.010	0.010	---	---	---	---	0.01
near mouth (Nye)	SRT	1/17/72	1.1	---	7.8	146	---	---	---	---	---	---	18.6	5.6	69	1.8	1.1	0.1	79	65	8	0.7	0.0	0.2	---	0.0	0.0	0.010	0.010	---	---	---	---	0.01
near mouth (Nye)	SRT	2/16/72	1.1	---	7.8	152	---	0	---	---	---	---	21.0	4.9	71	1.9	1.0	0.1	86	70	---	0.4	0.0	0.7	---	0.0	0.0	0.010	0.010	---	---	---	---	0.01
near mouth (Nye)	FC	Minimum	0.0	---	6.9	---	40	0	---	9.0	---	---	5.0	0.5	21	0.8	0.5	---	22	21	2.2	0.2	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
near mouth (Nye)	FC	Mean	5.6	---	8.3	---	90	0	---	10.8	---	---	13.0	4.0	48	1.6	0.9	---	57	47	5.9	0.4	0.0	0.2	---	0.10	0.0	<.01	<.01	---	---	---	---	<.01
near mouth (Nye)	FC	Maximum	11.8	---	8.6	---	132	2	---	12.8	---	---	21.0	6.7	76	2.4	1.8	---	94	76	8.6	1.1	0.1	1.0	---	0.92	0.1	0.02	0.02	---	---	---	---	<.01
Cresent Creek	SRT	7/8/71	8.0	2	7.3	62	---	---	---	---	---	---	4.2	5.2	32	1.0	0.7	0.1	33	27	6	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Cresent Creek	SRT	8/17/71	10.1	2	7.7	---	54	---	---	---	---	---	8.4	8.0	90	1.1	1.0	---	63	52	6	0.5	0.9	0.3	---	0.0	0.0	0.005	0.003	0.010	0.004	---	0.005	0.005
Cresent Creek	SRT	8/20/71	---	0.2	7.9	114	---	---	---	---	---	---	7.9	8.6	55	1.2	0.7	0.1	59	49	1	0.2	0.0	0.0	---	0.0	0.020	0.010	---	---	0.002	---	0.005	---
Cresent Creek	FC	Minimum	5.6	---	8.4	---	86	1	---	9.0	---	---	5.1	8.0	46	0.5	0.4	---	52	43	3.8	0.2	0.0	0.0	---	0.10	0.0	---	---	---	---	---	---	---
Cresent Creek	FC	Maximum	10.1	---	8.5	---	99	6	---	9.6	---	---	6.5	9.2	54	0.8	0.5	---	59	48	7.3	0.7	0.0	0.3	---	0.55	0.03	<.01	<.01	---	---	---	---	<.01
Salerbalm (Sodderholm) Creek	SRT	7/8/71	7.5	39	6.8	14	---	---	---	---	---	---	1.6	1.9	12	1.1	0.5	0.1	4	4	2	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Salerbalm (Sodderholm) Creek	SRT	8/20/71	---	9	6.6	16	---	---	---	---	---	---	0.8	0.4	4	1.4	0.5	0.3	8	7	0.4	0.2	0.0	0.0	0.05T	0.0	0.0	---	---	---	0.002	---	0.015	0.010
Cathedral Creek	SRT	6/24/71	9.0	45	6.7	23	---	---	---	---	---	---	2.4	0.7	9	1.8	1.7	0.3	9	7	7	0.5	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
Cathedral Creek	SRT	8/5/71	9.0	5	7.3	46	---	---	---	---	---	---	1.6	1.6	12	2.2	1.0	0.3	22	18	2	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Cathedral Creek	FC	Minimum	0.0	---	0.3	---	48	0	---	8.7	---	---	3.5	2.8	20	1.6	0.3	---	27	22	2.4	0.3	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
Cathedral Creek	FC	Maximum	2.2	---	8.3	---	50	2	---	10.8	---	---	4.1	2.9	22	2.1	0.5	---	28	23	3.9	0.3	0.0	0.2	---	0.06	0.0	0.01	<.01	---	---	---	---	<.01
Initial Creek	SRT	6/24/71	9.0	9	8.2	190	106	---	---	---	---	---	30	78	161	1.4	1.0	0.1	117	94	4	0.0	0.08	0.1	0.05T	0.0	0.004	0.087	0.007	0.011	0.002	---	0.010	0.005
Initial Creek	SRT	8/5/71	9.0	1	8.2	247	---	---	---	---	---	---	35	9.7	127	2.0	1.0	0.1	153	125	5	0.3	0.0	0.0	---	0.0	0.0	---	0.010	---	0.002	---	0.005	---
Initial Creek	SRT	8/18/71	11.2	1	8.5	---	132	---	---	---	---	---	36	10.4	216	1.9	1.0	---	155	147	4	0.5	0.10	0.3	---	0.0	0.0	0.005	0.007	0.010	0.001	---	0.005	0.005
Initial Creek	SRT	11/2/71	0.0	---	8.6	---	121	---	---	---	---	---	32	10.3	186	1.0	0.5	---	128	118	3	1.0	0.10	0.0	0.0T	0.0	0.0	0.005	0.005	0.010	0.001	---	0.010	0.005
Initial Creek	FC	Minimum	0.0	---	8.6	---	157	0	---	9.7	---	---	23	8.2	90	1.4	0.3	---	112	92	1.6	0.2	0.0	0.0	---	0.02	0.01	<.01	<.01	---	---	---	---	<.01
Initial Creek	FC	Maximum	2.2	---	8.6	---	220	4	---	10.8	---	---	34	11.3	130	2.1	0.4	---	154	126	7.8	0.2	0.0	0.1	---	0.05	0.01	0.01	<.01	---	---	---	---	<.01
Iron Creek:																																		
near headwaters	SRT	7/20/71	6.7	2	6.9	26	---	1.2	19	---	---	---	0.9	1.8	---	0.1	0.1	---	17	14	0.1	0.1	---	---	---	0.030	---	---	0.002	---	---	---	0.009	---
near headwaters	SRT	9/15/71	2.2	2	7.2	60	---	1.4	43	---	---	---	1.5	6.1	---	0.4	0.2	---	35	29	2	0.2	---	---	---	0.050	---	---	0.001	---	---	---	0.004	---
at mouth	SRT	6/25/71	5.0	127	7.3	44	---	---	---	---	---	---	8.1	0.9	24	0.9	0.4	0.1	26	21	1	0.4	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
at mouth	SRT	8/18/71	13.4	36	7.1	---	19	---	---	---	---	---	5.6	1.2	42	1.2	1.0	---	---	88	5	0.5	0.04	0.4	---	0.0	0.0	0.017	0.005	0.010	0.004	---	0.005	0.035
at mouth	FC	Minimum	2.2	---	7.7	---	75	0	---	5.0	---	---	10.7	2.9	39	1.0	0.3	---	40	39	2.6	0.3	0.0	0.0	---	0.06	0.01	<.01	<.01	---	---	---	---	<.01
at mouth	FC	Maximum	3.9	---	8.3	---	171	7	---	13.0	---	---	21.0	4.5	70	1.7	0.8	---	87	72	5.4	0.3	0.0	0.2	---	0.06	0.01	0.01	<.01	---	---	---	---	<.01
Picket Pin Creek	SRT	7/9/71	6.5	26	7.3	54	---	---	---	---	---	---	8.7	1.2	26	1.5	0.3	0.1	25	21	4	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Picket Pin Creek	SRT	9/16/71	3.0	9	7.9	119	---	---	---	---	---	---	15.4	2.8	49	1.8	0.4	0.6	66	54	0.4	0.5	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
Picket Pin Creek	FC	Minimum	0.0	---	8.2	---	65	0	---	9.7	---	---	10.7	1.4	32	1.3	0.2	---	40	33	2.0	0.3	0.0	0.0	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
Picket Pin Creek	FC	Maximum	2.2	---	8.6	---	69	7	---	10.3	---	---	15.0	3.0	49	1.7	0.2	---	55	45	4.7	0.3	0.0	0.3	---	0.05	0.02	0.015	<.01	---	---	---	---	<.01
East and West Rosebud Creeks and Tributaries																																		
West Rosebud Creek:																																		
near Pine Grove	WQB	11/4/69	4.0	---	7.1	---	---	0.32	---	10.0	---	---	4.0	1.2	15	---	---	---	---	18	1.0	3.8	0.15	0.004	0.06	0.01	0.0	---	0.02	---	---	---	0.02	---
near Pine Grove	WQB	8/6/70	16.0	---	7.5	---	50	---	---	---	---	---	5.6	0.7	17	0.4*	---	---	30	---	4.5	0.0	0.0	0.05	---	0.0	---	---	0.01	0.0	0.0	---	---	---
near Pine Grove	WQB	8/6/70	18.0	---	7.7	---	40	---	---	---	---	---	5.2	1.4	19	1.2*	---	---	30	---	5.0	0.0	0.1	0.08	---	0.03	---	---	0.01	0.0	0.0	---	---	---
near Pine Grove	SRT	2/9/71	0.3	---	6.8	42	---	---	---	---	---	---	5.0	0.2	13	1.3	0.6	0.2	20	16	6	0.1	0.0	0.0	---	0.0	0.020	---	---	---	---	---	---	0.010
near Pine Grove	SRT	4/12/71	2.2	20	6.7	37	---	---	---	---	---	---	3.9	0.4	11	1.2	1.1	0.2	17	14	2	1.0	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near Pine Grove	SRT	6/9/71	4.4	80	7.1	31	---	---	---	---	---	---	4.2	0.5	12	1.1	1.0	0.1	14	11	3	1.0	0.1	0.0	---	0.0	0.010	0.010	0.010	---	---	---	---	---
near Pine Grove	SRT	7/13/71	14.0	---	6.8	32	---	---	---	---	---	---	3.2	0.4	10	2.1	1.6	0.3	12	10	5	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near Pine Grove	SRT	7/26/71	13.4	60	6.7	27	---	---	---	---	---	---	2.6	1.0	11	1.0	0.7	0.1	10	8	3	0.4	0.0	0.0	---	0.0	0.0	0.010	---	---	---	---	---	---
near Pine Grove	SRT	9/21/71	4.0	99	6.9	32	---	---	---	---	---	---	2.8	0.9	11	1.0	0.7	0.1	15	12	1	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near Pine Grove	SRT	10/20/71	3.9	150	6.8	35	---	---	---	---	---	---	3.8	1.0	14	1.3	0.8	0.2	15	12	5	0.4	0.0	0.0	---	0.0	0.0	---	0.010	---	---	---	---	0.010
near Pine Grove	SRT	11/11/71	---	---	7.2	65	---	---	---	---	---	---	10.5	1.2	31	1.0	0.8	0.1	34	28	6	0.4	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Pine Grove	SRT	2/10/72	0.0	---	6.6	35	---	0	---	---	---	---	4.6	0.8	14	0.9	0.7	0.1	17	14	3	0.4	0.0	0.2	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Pine Grove	FC	Minimum	0.0	---	7.9	---	20	0	---	8.6	---	---	2.6	0.4	10	0.7	0.4	---	10	8	2.0	0.1	0.0	0.0	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
near Pine Grove	FC	Mean	6.2	---	8.1	---	30	3	---	11.1	---	---	4.3	0.9	15	1.0	0.8	---	17	14	3.2	0.5	0.0	0.3	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
near Pine Grove	FC	Maximum	14.0	---	8.3	---	58	8	---	12.0	---	---	10.5	1.3	31	1.3	1.1	---	34	28	6.2	1.4	0.1	0.8	---	0.07	0.01	0.01	<.01	---	---	---	---	<.01
below Pine Grove	WQB	0/6/70	18.0	---	7.6	---	50	---	---	---	---	---	14	1.2	40	0.4*	---	---	60	---	7	0.0	0.0	0.0	---	0.15	---	---	0.01	0.0	0.0	---	---	---
below Pine Grove	SRT	4/12/71	3.9	25	7.0	47	---	---	---	---	---	---	5.7	0.1	15	1.9	1.2	0.2	22	18	4	1.0	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
below Pine Grove	SRT	6/9/71	5.3	135	6.7	34	---	---	---	---	---	---	4.7	0.6	14	1.3	1.1	0.2	15	12	4	0.5	0.1	0.0	---	0.0	0.010	0.010	0.010	---	---	---	---	---
below Pine Grove	SRT	7/26/71	14.6	100	8.4	56	---	---	---	---	---	---	8.6	1.1	26	1.1	0.8	0.1	27	26	7	0.5	0.0	0.0	---	0.0	0.0	0.010	---	---	---	---	---	---
below Pine Grove	SRT	10/20/71	6.7	---	6.9	42	---	---	---	---	---	---	4.2	1.4	16	1.6	0.9	0.2	18	15	5	0.4	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
below Pine Grove	SRT	11/11/71	---	---	7.0	47	---	---	---	---	---	---	6.3	1.0	20	1.4	0.9	0.1	22	18	5	0.4	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
below Pine Grove	SRT	2/10/71	0.0	---	6.7	42	---	0	---	---	---	---	4.7	1.1	16	1.3	0.8	0.1	20	17	4	0.3	0.0	0.3	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
below Pine Grove	FC	Minimum	0.0	---	7.9	---	28	0	---	8.3	---	---	3.3	0.6	12	0.0	0.6	---	15	12	2.2	0.1	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
below Pine Grove	FC	Mean	6.7	---	8.2	---	37	2	---	10.9	---	---	5.2	0.9	17	1.3	0.8	---	20	17	4.4	0.4	0.0	0.2	---	0.03	0.0	<.01	<.01	---	---	---	---	<.01
below Pine Grove	FC	Maximum	15.7	---	8.4	---	49	3	---	12.0	---	---	8.6	1.4	26	1.9	1.2	---	27	26	7.4	1.0	0.1	0.7	---	0.17	0.01	0.01	<.01	---	---	---	---	<.01
West Fishtail Creek	SRT	7/13/71	11.5	24	6.7	19	---	---	---	---	---	---	1.9	0.3	6	1.1	0.7	0.2	7	6	1	0.1	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
West Fishtail Creek	SRT	9/21/71	3.0	12	7.1	34	---	---	---	---	---	---	2.5	1.0	10	1.5	0.6	0.2	14	12	0.4	0.1	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
West Fishtail Creek	SRT	2/14/72	0.6	---	7.2	63	---	0	---	---	---	---	8.7	1.0	25	2.5	0.9	0.2	32	27	5	0.5	0.0	0.2	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010

Table 12
(Continued)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	OS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA
West Fishtail Creek	FG	Minimum	0.0	---	8.1	---	78	0	---	9.6	---	--	3.0	0.6	10	1.0	0.6	---	15	12
West Fishtail Creek	FG	Mean	4.5	---	8.3	---	44	1	---	10.7	---	--	5.1	1.1	17	1.9	0.7	---	22	18
West Fishtail Creek	FG	Maximum	11.2	---	8.5	---	62	5	---	11.6	---	--	8.7	1.6	25	2.5	0.9	---	32	27
East Fishtail Creek	FG	Minimum	0.0	---	8.4	---	86	5	---	10.4	---	--	10.2	3.8	41	2.5	0.6	---	52	43
East Fishtail Creek	FG	Maximum	5.0	---	8.5	---	89	12	---	11.5	---	--	10.8	3.8	43	3.7	0.7	---	55	45
East Rosebud Creek:																				
above lake	WQB	11/5/69	3.0	---	6.95	---	---	0.2	---	10.0	---	--	4.0	1.2	15	---	---	---	---	18
above lake	SRT	7/14/71	8.5	---	6.7	21	---	---	---	---	---	--	1.9	0.7	8	0.8	0.6	0.1	8	7
above lake	SRT	9/21/71	4.0	24	7.1	26	---	---	---	---	---	--	2.6	1.0	10	0.6	0.6	0.1	11	9
near Jimmie Joe Campground	WQB	11/5/69	6.0	---	7.05	---	---	0.3	---	9.0	---	--	6.0	1.2	20	---	---	---	---	23
near Jimmie Joe Campground	WQB	8/6/70	15.0	---	7.7	---	12	---	---	---	---	--	2.7	0.7	9.7	0.1*	---	---	12	---
near Jimmie Joe Campground	SRT	4/12/71	1.1	22	6.8	46	---	---	---	---	---	--	5.2	0.6	15	1.3	1.4	0.1	21	18
near Jimmie Joe Campground	SRT	6/9/71	4.3	110	7.1	32	---	---	---	---	---	--	4.4	0.4	13	0.9	1.0	0.1	14	12
near Jimmie Joe Campground	SRT	7/26/71	11.6	60	6.8	23	---	---	---	---	---	--	2.0	1.0	9	0.8	0.7	0.1	10	8
near Jimmie Joe Campground	SRT	10/20/71	3.4	150	7.0	36	---	---	---	---	---	--	4.0	1.2	15	1.1	0.8	0.1	16	13
near Jimmie Joe Campground	SRT	11/11/71	---	---	6.9	42	---	---	---	---	---	--	5.6	1.0	18	0.8	0.9	0.1	19	15
near Jimmie Joe Campground	SRT	7/14/71	---	---	6.6	27	---	---	---	---	---	--	2.6	0.8	10	1.4	1.0	0.2	11	9
near Jimmie Joe Campground	SRT	9/21/71	---	74	7.1	34	---	---	---	---	---	--	3.3	1.2	13	1.9	0.7	0.1	17	14
near Jimmie Joe Campground	FG	Minimum	0.0	---	8.2	---	19	0	---	8.5	---	--	2.0	0.6	9	0.5	0.5	---	10	8
near Jimmie Joe Campground	FG	Mean	6.2	---	8.3	---	21	1	---	11.2	---	--	4.1	1.1	14	0.9	0.8	---	17	14
near Jimmie Joe Campground	FG	Maximum	14.0	---	8.4	---	38	4	---	13.0	---	--	5.7	1.5	20	1.3	1.4	---	24	20
near Down Bridge	WQB	8/6/70	17.0	---	7.7	---	30	---	---	---	---	--	3.3	1.0	12	0.8*	---	---	30	---
near Down Bridge	WQB	8/6/70	17.0	---	7.7	---	40	---	---	---	---	--	3.8	1.2	14	0.2*	---	---	30	---
near Down Bridge	SRT	2/9/71	0.9	---	7.1	76	---	---	---	---	---	--	8.8	1.3	27	2.6	0.9	0.2	39	32
near Down Bridge	SRT	4/12/71	3.9	30	7.0	72	---	---	---	---	---	--	7.7	1.7	25	2.4	1.7	0.2	35	29
near Down Bridge	SRT	6/9/71	5.0	200	6.8	35	---	---	---	---	---	--	4.2	1.6	17	1.1	1.1	0.1	16	13
near Down Bridge	SRT	7/26/71	13.2	100	6.9	27	---	---	---	---	---	--	2.6	1.0	11	1.0	0.7	0.1	11	9
near Down Bridge	SRT	10/20/71	3.9	150	7.2	49	---	---	---	---	---	--	5.7	1.6	21	1.5	1.0	0.1	23	19
near Down Bridge	SRT	11/14/71	3.9	---	7.1	59	---	---	---	---	---	--	8.1	1.5	26	1.5	0.1	0.1	29	24
near Down Bridge	SRT	7/16/72	0.0	---	7.1	68	---	3	---	---	---	--	8.6	1.6	28	1.7	1.0	0.1	36	30
near Down Bridge	FG	Minimum	0.0	---	8.1	---	22	0	---	8.5	---	--	2.6	0.7	10	0.6	0.6	---	11	9
near Down Bridge	FG	Mean	6.2	---	8.2	---	42	2	---	11.3	---	--	5.6	1.4	20	1.4	0.8	---	24	20
near Down Bridge	FG	Maximum	15.7	---	8.4	---	60	3	---	13.0	---	--	8.6	1.8	28	2.4	1.7	---	36	30
Morris Creek	WQB	8/6/70	23.0	---	---	---	90	---	---	---	---	--	26	4.0	82	10.2*	---	---	130	---
Morris Creek	FG	Minimum	0.0	---	8.3	---	106	8	---	7.1	---	--	10.8	2.2	39	7.0	0.7	---	66	54
Morris Creek	FG	Mean	7.3	---	8.4	---	150	18	---	10.7	---	--	16.5	3.6	56	12.0	1.0	---	92	75
Morris Creek	FG	Maximum	21.2	---	8.4	---	187	35	---	12.1	---	--	20.0	4.9	70	17.0	1.4	---	115	84

Sampling Site	Data Source	Date	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
West Fishtail Creek	FG	Minimum	2.6	0.1	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
West Fishtail Creek	FG	Mean	4.4	0.3	0.0	0.4	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
West Fishtail Creek	FG	Maximum	5.6	0.6	0.0	0.8	---	0.05	0.0	0.015	<.01	---	---	---	---	<.01
East Fishtail Creek	FG	Minimum	4.2	0.4	0.0	0.0	---	0.06	0.0	<.01	<.01	---	---	---	---	<.01
East Fishtail Creek	FG	Maximum	6.0	0.5	0.0	0.7	---	0.21	0.0	0.01	<.01	---	---	---	---	<.01
East Rosebud Creek:																
above lake	WQB	11/5/69	1.0	3.8	0.12	0.004	0.04	0.0	0.0	---	0.03	---	---	---	0.03	---
above lake	SRT	7/14/71	1.0	0.5	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
above lake	SRT	9/21/71	0.4	1.0	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
near Jimmie Joe Campground	WQB	11/5/69	1.0	2.5	0.11	0.006	0.08	0.02	0.0	---	0.01	---	---	---	0.03	---
near Jimmie Joe Campground	WQB	8/6/70	4	0.0	0.0	0.05	---	0.02	---	---	0.01	0.0	0.0	---	---	---
near Jimmie Joe Campground	SRT	4/12/71	4	0.5	.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near Jimmie Joe Campground	SRT	6/9/71	6	1.0	0.1	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	---
near Jimmie Joe Campground	SRT	7/26/71	2	0.2	0.0	0.4	---	0.0	0.0	0.010	---	---	---	---	---	---
near Jimmie Joe Campground	SRT	10/20/71	5	0.2	0.0	0.4	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Jimmie Joe Campground	SRT	11/11/71	5	0.5	0.0	0.0	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Jimmie Joe Campground	SRT	7/14/71	2	1.0	---	0.0	---	0.0	0.0	---	0.010	---	0.002	---	0.005	---
near Jimmie Joe Campground	SRT	9/21/71	1	1.0	---	0.0	0.05T	0.0	0.0	---	0.010	---	0.001	---	0.005	0.0.0
near Jimmie Joe Campground	FG	Minimum	1.8	0.0	0.0	0.0	---	0.0	0.0	<.01	<.01	---	---	---	---	<.01
near Jimmie Joe Campground	FG	Mean	3.6	0.3	0.0	0.3	---	0.02	0.0	<.01	<.01	---	---	---	---	<.01
near Jimmie Joe Campground	FG	Maximum	6.0	1.0	0.1	0.7	---	0.08	0.0	0.01	<.01	---	---	---	---	<.01
near Down Bridge	WQB	8/6/70	2	0.0	0.05	0.05	---	0.04	---	---	0.01	0.01	0.0	---	---	---
near Down Bridge	WQB	8/6/70	3	0.0	0.1	0.05	---	0.06	---	---	0.01	0.0	0.0	---	---	---
near Down Bridge	SRT	2/9/71	11	0.1	0.0	1.0	---	0.0	0.020	---	---	---	---	---	---	0.0.0
near Down Bridge	SRT	4/12/71	5	0.5	0.0	0.0	---	0.0	0.0	---	---	---	---	---	---	---
near Down Bridge	SRT	6/9/71	3	1.0	0.1	0.0	---	0.0	0.010	0.010	0.010	---	---	---	---	---
near Down Bridge	SRT	7/26/71	3	0.3	0.0	0.4	---	0.0	0.0	0.010	---	---	---	---	---	---
near Down Bridge	SRT	10/20/71	4	0.3	0.0	0.4	---	0.0	0.0	---	0.010	---	---	---	---	0.010
near Down Bridge	SRT	11/14/71	6	0.5	0.0	0.1	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Down Bridge	SRT	7/16/72	3	1.0	0.0	0.8	---	0.0	0.0	0.010	0.010	---	---	---	---	0.010
near Down Bridge	FG	Minimum	2.6	0.1	0.0	0.0	---	<.02	0.0	<.01	<.01	---	---	---	---	<.01
near Down Bridge	FG	Mean	3.9	0.5	0.0	0.4	---	0.12	0.0	<.01	<.01	---	---	---	---	<.01
near Down Bridge	FG	Maximum	5.6	1.4	0.1	0.9	---	0.41	0.01	0.01	<.01	---	---	---	---	<.01
Morris Creek	WQB	8/6/70	8	0.0	0.2	0.03	---	0.6	---	---	0.01	0.0	0.0	---	---	---
Morris Creek	FG	Minimum	2.0	0.3	0.0	0.2	---	0.46	0.0	<.01	<.01	---	---	---	---	<.01
Morris Creek	FG	Mean	6.6	0.8	0.1	0.4	---	0.71	0.10	<.01	<.01	---	---	---	---	<.01
Morris Creek	FG	Maximum	9.6	1.3	0.2	1.0	---	1.10	0.36	0.01	<.01	---	---	---	---	<.01

With the exceptions listed below, samples analyzed for the following constituents were less than or equal to the listed values (mg/l):
Al--<.4; Ag--<.001; Co--<.002; Hg--<.001; Mo--<.005; Ni--<.05; Se--<.004; V--<.05; Ba and Be=0.0.
Stillwater River near headwaters: Al--5.6 to 23.0 mg/l; Mo--0.2 to 2.0 mg/l; Sb--0.10 mg/l (one sample).
Verdigris Creek: Ni--0.09 to 0.59 mg/l.
Stillwater River near Beehive (single samples): Ba--0.100 mg/l; Mo--0.007 mg/l; Se--0.030, 0.008 mg/l.

basins respectively (Ref. /17 & 18). These data indicate an excellent and relatively clear-type of water in the sub-basin. High turbidities and sediments were obtained primarily during high flow periods or in portions of a stream near mining operations. None of the water quality standards and criteria summarized in Table 9 were exceeded in water from most samples collected from the Stillwater River sub-basin. In some samples obtained from the Stillwater near mining operations, pH values were less than the minimum levels suited for public supply, stock water, and aquatic life (Ref. 7). None of the common constituents had concentrations in excess of recommended levels. Iron, manganese, lead, chromium, and cadmium occasionally approached and exceeded the criteria established for these constituents.

Samples from the headwaters of the Stillwater River (Table 12) provide an excellent example of the effects of acid mine drainage on a low alkalinity, poorly buffered stream with low flows. The river has a normal alkalinity in this reach ranging from 40 to 60 mg/l as $CaCO_3$ with pH's between 7.2 and 8.0. After inputs of acid discharge, alkalinity is reduced to zero which eliminates buffering capacity; pH is reduced to between 2.5 and 4.2. With the flows of the Stillwater in this reach (about 0.5 cfs), an acid load of approximately 7.1 mg/l/-sec. (i.e., an input of 7.1 millimoles of H^+ per second) would be required to bring about this alteration. This is equivalent to the addition of only 0.6 ml of concentrated hydrochloric to the stream per second (about 12 drops). Simultaneously, metal concentrations increase in the stream from the acid inputs. As a result, iron, lead, manganese, copper, chromium, cadmium, aluminum, and molybdenum concentrations are high in this reach in comparison to those downstream and in the other streams. Fortunately, numerous tributaries and groundwater enter the Stillwater River below this mine discharge and the stream quickly recovers--alkalinity and pH return to normal ranges and the metals are diluted to lower levels.

A wide range of pH is evident in the streams of the sub-basin; these vary from 6.5 to near 8.5 which is attributable primarily to natural causes. Temperatures range from 0°C in the winter to 8-18°C in the summer which is typical of cold water habitats. Dissolved oxygen was found to be near saturation in all cases (much greater than 5 mg/l) varying as a function of temperature and altitude rather than a function of organic loading. These chemical and physical characteristics make the stream well suited as a trout stream (Appendix B).

<u>Clarks Fork Yellowstone River Sub-basin</u>

Several water quality and sediment monitoring sites and continuous-record and partial-record discharge gaging stations are currently or have been previously operated by the USGS in the Clarks Fork Yellowstone River sub-basin (Table 8). In addition, some water quality data for the sub-basin is available from the Montana Water Quality Bureau and STORET. Selected USGS data and other water quality information is summarized in Table 13.

Table 13

Typical Chemical Analyses of Water in the Clarks Fork Yellowstone River Sub-basin (43D)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Clarks Fork Yellowstone River Mainstem																																		
near Chance	USGS	10/9/67	13	483	8.1	250	146	---	---	---	---	---	30	8.5	110	8.6	1.2	0.4	120	---	29	0.8	0.3	0.6	---	0.05	---	---	---	---	---	0.01	---	---
near Chance	USGS	1/23/68	3	284	8.0	373	214	---	---	---	---	---	43	14	164	11	1.3	0.4	155	---	58	1.2	0.2	0.4	---	0.02	---	---	---	---	---	0.04	---	---
near Chance	USGS	4/1/68	---	357	8.0	304	186	---	---	---	---	---	38	10	138	9.4	1.2	0.4	136	---	49	1.4	0.1	0.2	---	0.03	---	---	---	---	---	0.02	---	---
near Chance	USGS	6/25/68*	12	5310	8.1	122	62	---	---	---	---	---	12	2.1	51	2.9	0.3	0.2	60	---	2.3	1.0	0.1	0.2	---	---	---	---	---	---	---	0.0	---	---
near Chance	USGS	9/23/68*	13	503	7.7	239	132	---	---	---	---	---	30	2.1	104	8.3	1.2	0.4	111	---	32	0.6	0.1	0.0	---	---	---	---	---	---	---	0.02	---	---
near Chance	USGS	2/21/69*	1.0	239	7.6	349	230	---	---	---	---	---	44	12	160	11	2.0	0.4	115	---	54	1.2	0.2	0.5	---	---	---	---	---	---	---	0.01	---	---
near Chance	USGS	5/6/69*	14.0	1150	7.7	115	92	---	---	---	---	---	17	3.3	56	4.9	1.1	0.3	69	---	10	0.6	0.0	0.2	---	---	---	---	---	---	---	0.0	---	---
near Chance	USGS	6/7/69*	13.0	3320	8.0	100	64	---	---	---	---	---	12	2.4	40	3.5	0.4	0.2	50	---	8.2	0.2	0.1	0.0	---	---	---	---	---	---	---	0.0	---	---
near Chance	USGS	9/10/69*	17.0	181	7.6	333	212	---	---	---	---	---	42	13	145	12	2.0	0.4	178	---	33	1.2	0.2	0.6	---	---	---	---	---	---	---	0.02	---	---
near Chance	USGS	4/16/70	7.0	193	8.3	342	204	---	---	---	---	---	41	13	156	12	1.0	0.4	140	---	54	1.5	0.3	0.1	---	---	---	---	---	---	---	0.0	---	---
near Chance	USGS	6/2/70	12.0	2040	7.6	100	66	---	---	---	---	---	12	3.1	42	4.2	0.6	0.3	52	---	8.2	1.6	0.0	0.1	---	0.06	---	---	---	---	---	0.01	---	---
near Chance	USGS	9/16/70	14.0	552	7.9	284	166	---	---	---	---	---	33	8.8	118	13	1.3	0.5	130	---	36	0.7	0.1	1.0	---	0.02	---	---	---	---	---	0.01	---	---
near Chance	USGS	12/10/70	1.5	346	8.3	299	182	---	---	---	---	---	42	9.1	140	9.2	1.1	0.3	140	---	42	5.0	0.2	0.4	---	0.06	---	---	---	---	---	0.0	---	---
near Chance	USGS	5/13/71	---	2900	7.9	152	101	---	---	---	---	---	23	3.1	70	5.3	0.9	0.3	81	---	16	1.1	0.5	0.5	---	0.21	---	---	---	---	---	0.02	---	---
near Chance	USGS	6/8/71	10.0	4710	7.7	106	61	---	---	---	---	---	15	1.6	45	2.2	0.4	0.1	55	---	4.9	0.3	0.1	0.3	---	0.03	---	---	---	---	---	0.01	---	---
near Chance	USGS	9/8/71	16.0	823	8.4	198	120	---	---	---	---	---	29	4.4	90	6.0	1.3	0.3	85	---	20	1.0	0.2	0.6	---	0.14	---	---	---	---	---	0.01	---	---
near Chance	USGS	12/2/71	1.5	267	8.3	337	209	---	---	---	---	---	43	12	160	11	1.1	0.4	153	---	53	3.1	0.2	0.1	---	0.07	---	---	---	---	---	0.01	---	---
near Chance	USGS	3/6/72	6.0	271	8.1	381	228	---	---	---	---	---	47	12	160	14	1.2	0.5	130	---	78	2.1	0.2	0.2	---	0.09	---	---	---	---	---	0.02	---	---
near Chance	USGS	6/1/72	9.5	6520	7.9	89	50	---	---	---	---	---	13	2.0	41	2.9	0.7	0.2	48	---	7.4	0.0	0.1	0.2	---	0.04	---	---	---	---	---	0.02	---	---
near Chance	USGS	7/13/72	14.5	3120	7.7	95	56	---	---	---	---	---	11	3.2	40	3.5	0.5	0.2	49	---	5.8	0.7	0.1	0.2	---	0.0	---	---	---	---	---	0.02	---	---
near Chance	USGS	8/30/72	19.5	950	8.5	217	129	---	---	---	---	---	27	6.8	95	7.5	1.2	0.3	101	---	21	1.3	0.2	0.3	---	0.12	---	---	---	---	---	0.03	---	---
near Chance	USGS	1/17/73	2.5	316	8.1	330	192	---	---	---	---	---	41	10	150	9.6	1.4	0.3	131	---	53	2.0	0.2	---	---	0.10	---	---	---	---	---	0.02	---	---
near Chance	USGS	4/10/73	11.0	229	8.5	374	230	---	---	---	---	---	46	14	170	14	1.4	0.5	153	---	62	3.5	0.2	0.2	---	0.10	---	---	---	---	---	0.02	---	---
near Chance	USGS	6/11/73	11.5	4400	7.9	82	52	---	---	---	---	---	11	1.4	34	3.2	0.5	0.2	41	---	5.8	1.8	0.1	0.4	---	0.16	---	---	---	---	---	0.01	---	---
near Chance	USGS	7/9/73	19.0	2030	8.0	101	58	---	---	---	---	---	13	2.1	41	3.2	0.5	0.2	48	---	2.4	0.4	0.1	0.2	---	0.10	---	---	---	---	---	0.02	---	---
near Chance	USGS	8/2/73	15.5	534	8.3	215	127	---	---	---	---	---	28	5.4	93	8.0	0.9	0.4	104	---	23	1.1	0.2	0.4	---	0.10	---	---	---	---	---	0.02	---	---
near Chance	WQB	7/21/69	---	1080	7.55	---	---	0	---	---	---	---	15	5.5	60	---	---	---	---	65	18	1.2	---	---	---	---	---	---	---	---	---	---	---	---
near Chance	WQB	9/23/69	13.0	545	8.00	---	---	0	3	---	---	---	43	12.5	160	---	---	---	---	140	35	3.0	---	---	---	0.05	---	---	---	---	---	---	---	---
near Chance	WQB	9/3/69	---	---	7.25	---	---	0.47	---	---	---	---	6.0	2.4	25	---	---	---	---	30	2.0	2.5	1.28	0.002	0.07	---	---	---	0.02	---	---	---	0.02	---
near Belfry	WQB	7/23/69	---	---	7.50	---	---	13	17	---	---	---	22	3.4	70	---	---	---	---	80	24	0.8	---	---	---	---	---	---	---	---	---	---	---	---
near Belfry	WQB	9/21/69	12.0	---	7.90	---	---	21	11	---	---	---	58	18.0	220	---	---	---	---	195	74	7.0	---	---	0.22	0.11	---	---	---	---	---	---	---	---
above Silvertip Creek	WQB	7/21/69	20.0	---	8.50	---	---	6	19	---	---	---	25	5.8	87	---	---	---	---	78	26	2.2	---	---	---	---	---	---	---	---	---	---	---	---
above Silvertip Creek	WQB	9/21/69	18.0	---	7.80	---	---	100	222	---	---	---	68	14.4	230	---	---	---	---	220	125	7.0	---	---	---	---	---	---	---	---	---	---	---	---
near Bridger	WQB	7/23/69	22.0	---	8.45	---	---	11	16	---	---	---	28	7.4	100	---	---	---	---	80	32	2.8	---	---	---	---	---	---	---	---	---	---	---	---
near Bridger	WQB	9/23/69	18.0	---	7.80	---	---	7	7	---	---	---	70	20.4	260	---	---	---	---	235	110	7.0	---	---	---	---	---	---	---	---	---	---	---	---
near Fromberg	WQB	7/21/69	24.0	---	8.55	---	---	23	42	---	---	---	40	13.9	158	---	---	---	---	120	85	2.4	---	---	---	---	---	---	---	---	---	---	---	---
near Fromberg	WQB	9/21/69	14.0	---	7.80	---	---	5	15	---	---	---	108	10.8	315	---	---	---	---	280	375	17.0	---	---	---	---	---	---	---	---	---	---	---	---
near Edgar	WQB	7/23/69	21.0	1190	8.10	---	---	30	63	---	---	---	41	16.1	170	---	---	---	---	126	130	3.6	---	---	---	---	---	---	---	---	---	---	---	---
near Edgar	WQB	9/23/69	14.0	234	7.65	---	---	40	12	---	---	---	117	5.5	315	---	---	---	---	270	450	15.0	---	---	0.24	0.25	---	---	---	---	---	---	---	---
near Laurel	USGS	8/28/69*	21	165	8.3	1060	850	23	---	9.6	1.4	---	---	---	393	46	3.0	---	---	171	332	---	7	2.7	0.0	0.05	0.025	0.022	0.001	0.0	0.0	0.01	0.0	0.0
near Laurel	USGS	9/21/69	13	620	8.1	769	512	41	---	9.8	2.2	---	---	---	288	---	---	---	---	223	215	---	---	3.5	0.34	---	---	---	---	---	---	---	---	---
near Laurel	USGS	7/17/70*	---	430	---	---	459	40	---	---	2.0	---	---	---	274	46	2.6	---	---	---	184	---	0.3	2.66	0.04	0.048	0.073	0.038	0.0	0.0	0.001	---	0.0	0.0
near Laurel	USGS	6/18/70*	---	3300	---	---	158	70	---	---	1.0	---	---	---	96	21	1.7	---	---	---	48	---	0.3	0.75	0.01	0.172	0.010	0.0	0.017	0.0	0.003	0.055	0.0	0.0
near Laurel	USGS	7/27/70	---	1100	---	---	288	---	---	---	2.6	---	43	16	171	31	---	---	---	---	---	---	0.0	1.02	0.43T	---	0.008	0.0	0.0	0.0	0.004	0.053	0.0	0.0
near Laurel	USGS	11/3/70	8.0	850	7.9	630	334	---	---	12.4	---	---	61	20	240	38	---	---	---	---	---	3.2	0.1	2.22	0.06T	---	0.018	0.0	0.0	0.0	0.0	0.070	0.0	0.001
near Laurel	USGS	1/13/71	0.5	530	7.9	640	376	---	---	10.2	1.0	130	65	22	250	31	---	---	---	---	130	2.1	0.3	0.44	---	---	0.0	0.010	0.001	0.0	0.0	0.020	0.0	0.0
near Laurel	USGS	5/11/71	12.0	3000	8.2	255	150	---	---	8.4	1.2	2000	29	8.2	110	---	---	---	---	---	41	1.5	---	0.44	1.84T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	6/16/71	11.0	7500	---	160	168	---	---	8.6	0.6	510	15	4.1	54	---	---	---	---	---	16	0.6	---	0.35	0.92T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	8/12/71	23.0	1200	8.5	400	264	---	---	---	1.1	26	39	15	160	---	---	---	---	---	90	1.8	---	0.71	0.37T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	10/20/71	6.5	1000	8.0	700	436	---	---	7.8	1.6	300	56	20	220	41	---	1.2	---	---	150	5.8	0.2	1.59	0.58T	---	0.010	0.010	0.005	0.0	0.002	0.080	0.0	0.0
near Laurel	USGS	1/17/72	0.0	600	7.6	610	420	---	---	11.6	1.1	23	70	23	270	31	---	0.8	---	---	160	3.7	0.3	2.79	0.03T	---	0.020	0.020	0.006	0.0	0.002	0.060	0.0	0.001
near Laurel	USGS	4/17/72	10.0	550	8.1	625	462	---	---	10.8	0.6	11	66	23	260	42	---	1.1	---	---	170	4.3	0.3	0.35	0.15T	---	0.0	0.010	0.003	0.0	0.0	0.030	0.0	0.001
near Laurel	USGS	6/22/72	13.5	4500	7.7	180	172	---	---	8.8	1.1	370	19	5.6	70	---	---	---	---	---	29	1.1	---	0.66	0.58T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	7/14/72	17.0	3000	7.7	250	154	---	---	8.5	1.4	230	24	8.4	94	14	---	0.6	---	81	46	1.0	0.3	0.58	0.09	---	---	---	---	---	---	---	---	---
near Laurel	USGS	10/17/72	8.5	1200	8.4	490	322	---	---	9.0	1.6	49	52	18	204	30	---	0.9	---	124	120	2.4	0.3	0.71	0.03	---	---	---	---	---	---	---	---	---
near Laurel	USGS	1/16/73	0.5	640	7.8	625	412	---	---	11.0	1.5	70	65	22	253	35	---	1.0	---	159	150	3.2	0.4	2.44	0.03	---	---	---	---	---	---	---	---	---
near Laurel	USGS	5/18/73	6.5	1020	8.2	550	421	---	---	10.0	2.2	190	61	21	240	22	---	0.6	---	168	160	5.7	0.3	1.11	0.09	---	---	---	---	---	---	---	---	---
near Laurel	USGS	6/14/73	14.5	4790	7.1	190	119	---	---	8.2	1.8	470	18	5.3	67	11	---	0.6	---	60	30	1.2	0.2	---	---	---	---	---	---	---	---	---	---	---
near Laurel	USGS	8/15/73	20.5	516	8.1	720	476	---	---	10.8	2.1	270	65	27	270	55	---	1.4	---	193	200	4.0	0.3	1.13	0.0	---	---	---	---	---	---	---	---	---
near Laurel	WQB	3/13/67	0.0	260	7.6	---	516	100	---	---	---	---	80	28	---	65*	---	---	259	---	220	8	0.3	2.57	0.10	1.20	---	---	---	---	---	---	---	---
near Laurel	WQB	4/10/67	12.3	136	---	---	380	<25	---	---	---	---	57	21	---	50*	---	---	207	---	148	7	0.2	0.38	3.2	0.44	---	---	---	---	---	---	---	---
near Laurel	WQB	5/9/67	16.2	401	7.5	---	500	162	---	---	---	---	59	31	---	71*	---	---	250	---	200	8	0.5	1.28	0.09	2.6	---	---	---	---	---	---	---	---
near Laurel	WQB	6/1[illegible]/67	12.3	7970	---	---	170	2200	---	---	---	---	22	5	---	47*	---	---	143	---	49	5	0.1	0.89	1.09	0.48	---	---	---	---	---	---	---	---
near Laurel	WQB	7/10/67	16.2	5160	7.4	---	110	230	---	---	---	---	18	4	---	24*	---	---	98	---	28	3	0.1	0.67	0.04	0.57	---	---	---	---	---	---	---	---
near Laurel	WQB	8/1[illegible]/67	21.8	824	7.6	---	350	<25	---	---	---	---	48	54	---	48*	---	---	204	---	136	5	0.4	1.04	0.0	0.48	---	---	---	---	---	---	---	---
near Laurel	WQB	9/11/67	20.2	393	---	---	670	<25	---	---	---	---	80	28	---	105*	---	---	287	---	285	6	0.5	1.68	0.0	0.26	---	---	---	---	---	---	---	---
near Laurel	WQB	10/[illegible]/67	19.0	873	7.6	---	366	38	---	---	---	---	43	8	---	81*	---	---	217	---	138	6	0.4	1.39	0.0	1.20	---	---	---	---	---	---	---	---
near Laurel	WQB	11/13/67	7.3	642	7.6	---	370	<25	---	---	---	---	44	22	---	73*	---	---	214	---	161	5	0.32	1.63	0.1	0.0	---	---	---	---	---	---	---	---
near Laurel	WQB	12/11/67	0.0	420	7.5	---	420	<25	---	---	---	---	58	25	---	63*	---	---	238	---	164	5	0.4	2.78	0.0	0.27	---	---	---	---	---	---	---	---
near Laurel	WQB	1/10/68	0.0	440	7.3	---	490	0	---	---	---	---	70	23	---	65*	---	---	250	---	185	5	0.4	3.31	0.0	0.0	---	---	---	---	---	---	---	---
near Laurel	WQB	3/1[illegible]/68	3.4	398	7.5	---	460	3	---	---	---	---	56	24	---	67*	---	---	229	---	176	6	0.2	1.26	0.0	0.22	---	---	---	---	---	---	---	---
near Laurel	WQB	4/12/68	6.7	394	7.6	---	440	13	---	---	---	---	50	30	---	54*	---	---	214	---	162	6	0.04	1.27	0.0	0.0	---	---	---	---	---	---	---	---
near Laurel	WQB	5/17/68	17.4	580	7.5	---	430	5	---	---	---	---	72	15	---	67*	---	---	195	---	210	3	0.3	0.3	0.0	0.10	---	---	---	---	---	---	---	---
near Laurel	WQB	6/1[illegible]/68	12.9	4930	---	---	250	1500	---	---	---	---	32	2	---	28*	---	---	113	---	108	3	0.26	0.7	0.0	0.17	---	---	---	---	---	---	---	---
near Laurel	WQB	7/8/68	16.8	3160	8.6	---	110	40	---	---	---	---	20	4	---	23*	---	---	98	---	35	2	0.3	1.0	0.0	0.7	---	---	---	---	---	---	---	---
near Laurel	WQB	8/10/68	22.4	810	8.2	---	390	50	---	---	---	---	56	16	---	50*	---	---	201	---	133	5	0.7	1.1	0.0	1.4	---	---	---	---	---	---	---	---
near Laurel	WQB	9/2/74	15.0	737	8.49	681	491	---	45	11.2	4.4	4500	59	27	258	37	---	1.0	195	172	165	1.0	---	0.07	0.03	---	0.01	<.01	<.01	0.01	0.009	---	<.01	<.001
near Laurel	WQB	10/[illegible]/74	---	720E	8.04	666	524	---	20	10.5	---	---	65	25	261	43	---	1.2	221	181	169	0.0	---	1.8	0.13	0.53	0.05	<.01	<.01	<.01	0.001	0.11	<.01	<.001
near Laurel	WQB	11/19/74	4.0	650E	8.60	679	526	---	---	12.1	3.1	400	65	26	268	42	---	1.1	203	177	177	4.8	---	2.6	0.27	0.25	0.02	<.01	<.01	<.01	<.001	---	<.01	<.001
Tributaries																																		
Fl[illegible] Creek	SWT	8/[illegible]/71	11.0	2.1	[illegible].36	340	---	---	---	---	---	---	4.8	1.6	27	2.7	1.5	0.2	-	0	94	0.5	0.0	0.7	0.05T	0.001	0.810	---	---	0.100	0.002	---	0.005	0.010
Big Sand Coulee:																																		
near [illegible] line	WQB	7/21/69	---	---	---	---	---	165	414	---	---	---	24	4.1	77	---	---	---	---	90	80	3.4	---	---	---	---	---	---	---	---	---	---	---	---
near [illegible] line	WQB	9/21/69	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
near [illegible] (mouth)	WQB	7/21/69	---	---	---	---	---	120	103	---	---	---	37	8.6	128	---	---	---	---	131	85	4	---	---	---	---	---	---	---	---	---	---	---	---
near [illegible] (mouth)	WQB	9/21/69	16.8	---	---	---	---	60	124	---	---	---	56	12.0	190	---	---	---	---	185	85	8	---	---	---	0.35	---	---	---	---	---	---	---	---
Bear Creek	WQB	7/23/69	22.0	---	---	---	---	190	192	---	---	---	64	48	358	---	---	---	---	150	450	6	---	---	---	---	---	---	---	---	---	---	---	---
Bear Creek	WQB	9/23/69	18.0	---	---	---	---	1500	2204	---	---	---	75	61	440	---	---	---	---	240	425	8	---	---	2.3	1.4	---	---	---	---	---	---	---	---
Silvertip Creek	WQB	7/21/69	22.0	0.0	---	---	---	20	19	---	---	---	38	8.2	130	---	---	---	---	136	45	3	---	---	---	---	---	---	---	---	---	---	---	---
Silvertip Creek	WQB	9/21/69	15.0	0.7	---	---	---	20	3	---	---	---	84	20.4	195	---	---	---	---	260	58	10	---	---	---	0.25	---	---	---	---	---	---	---	---
Silvertip Creek	USGS	10/23/68	---	1.3	7.5	5770	4750	---	843	---	---	---	284	126	1210	940	67	12	318	---	2570	395	1.1	0.2	---	0.090	---	---	---	---	---	2.80	---	---
Silvertip Creek	USGS	12/6/68	---	0.78	7.9	5840	5860	---	436	---	---	---	728	128	1090	975	52	11	218	---	2530	417	0.8	0.5	---	0.190	---	---	---	---	---	2.50	---	---

Table 13
(Continued)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Silvertip Creek	USGS	3/17/69	---	3.8	8.0	3310	2590	---	1050	---	---	---	160	64	662	515	28	8.7	217	---	1320	193	0.8	1.6	---	0.200	---	---	---	---	---	0.98	---	---
Silvertip Creek	USGS	6/5/69	---	0.22	7.6	6120	5240	---	2430	---	---	---	288	130	1250	1050	56	13	314	---	2810	405	1.5	1.8	---	0.530	---	---	---	---	---	2.10	---	---
Silvertip Creek	USGS	12/2/69	0.0	0.41	7.9	6620	5400	---	443	---	---	---	270	154	1310	1250	57	15	278	---	3030	481	1.3	1.51	---	0.055	---	---	---	---	---	2.42	---	---
Silvertip Creek	USGS	3/7/70	1.0	3.8	7.8	4610	3470	---	6350	---	---	---	230	94	960	750	47	11	350	---	1910	249	1.0	1.37	---	0.118	---	---	---	---	---	1.50	---	---
Silvertip Creek	USGS	6/10/70	22.0	4.1	7.8	5420	4430	---	55100	---	---	---	335	127	1360	865	45	10	486	---	2490	300	1.2	0.22	---	0.105	---	---	---	---	---	2.24	---	---
Silvertip Creek	USGS	9/15/70	---	0.68	7.8	6160	4980	---	2840	---	---	---	285	105	1140	1110	76	14	334	---	2770	448	1.6	3.19	---	0.028	---	---	---	---	---	2.84	---	---
Silvertip Creek	USGS	2/15/71	0.0	16	7.4	2160	1600	---	2460	---	---	---	110	34	420	370	21	7.9	180	---	800	140	0.6	0.0	0.10	0.280	0.0	---	---	---	---	0.88	---	---
Silvertip Creek	USGS	3/12/71	0.5	8.1	7.4	3090	2100	---	25900	---	---	---	130	54	540	510	22	9.5	225	---	1100	160	0.8	0.44	0.20	0.140	0.150	---	---	---	---	---	---	---
Silvertip Creek	USGS	6/2/71	18.5	6.9	7.1	3720	2600	---	31500	---	---	---	170	62	680	600	14	10	283	---	1400	200	0.9	2.30	0.15	0.200	0.310	---	---	---	---	1.20	---	---
Silvertip Creek	USGS	9/4/71	13.0	8.5	7.0	3780	2890	---	3500	---	---	---	160	58	640	650	44	11	323	---	1600	230	1.3	2.66	0.12	0.020	0.140	---	---	---	---	1.60	---	---
Silvertip Creek	USGS	11/19/71	0.0	0.16	7.6	6880	5570	---	800	---	---	---	330	150	1400	1300	59	15	401	---	3000	510	1.4	0.89	---	0.030	0.010	---	---	---	---	2.30	---	---
Silvertip Creek	USGS	4/18/72	1.5	1.4	8.3	5960	4860	---	9000	---	---	---	270	120	1200	1100	53	14	333	---	2700	440	1.2	1.28	0.0	0.010	0.010	---	---	---	---	---	---	---
Silvertip Creek	USGS	6/10/72	14.0	19	7.3	2790	2070	---	40000	---	---	---	180	51	660	390	24	6.6	196	---	1200	110	0.7	6.20	0.06	0.030	0.340	---	---	---	---	0.710	---	---
Silvertip Creek	USGS	8/28/72	16.5	0.82	8.1	5860	4460	---	---	---	---	---	250	110	1100	1000	43	13	297	---	2400	500	1.4	2.22	0.0	0.090	0.0	---	---	---	---	---	---	---
Silvertip Creek	USGS	1/15/73	0.0	22	7.2	2180	1490	---	321	---	---	---	98	35	390	330	26	7.3	186	---	740	160	0.7	1.95	0.18	0.050	---	---	---	---	---	---	---	---
Silvertip Creek	USGS	2/27/73	0.5	4.4	8.0	4020	3110	---	568	---	---	---	180	75	760	670	33	11	289	---	1700	290	0.9	4.34	0.03	0.040	---	---	---	---	---	---	---	---
Silvertip Creek	USGS	4/25/73	5.5	39	7.4	2200	1510	---	33200	---	---	---	99	30	370	330	12	7.5	211	---	970	58	0.6	4.12	0.0	0.040	---	---	---	---	---	---	---	---
Silvertip Creek	USGS	6/30/73	23.5	0.82	7.1	6210	4930	---	2230	---	---	---	230	140	1200	1100	50	14	284	---	2800	450	1.2	0.44	0.06	0.020	---	---	---	---	---	---	---	---
Silvertip Creek	USGS	8/21/73	25.0	0.20	8.1	6790	5520	---	774	---	---	---	300	140	1300	1200	55	14	265	---	3200	470	1.3	0.09	0.06	0.020	---	---	---	---	---	---	---	---
Cottonwood Creek	WQB	7/23/69	22.0	---	---	---	---	95	205	---	---	---	52	46	320	---	---	---	---	133	400	2.8	---	---	---	---	---	---	---	---	---	---	---	---
Cottonwood Creek	WQB	9/23/69	16.0	---	---	---	---	67	190	---	---	---	78	43	375	---	---	---	---	255	500	21.0	---	---	0.4	0.3	---	---	---	---	---	---	---	---
Bluewater Creek	WQB	7/23/69	22.0	30	---	---	---	30	28	---	---	---	144	53	580	---	---	---	---	178	400	6.0	---	---	---	---	---	---	---	---	---	---	---	---
Bluewater Creek	WQB	9/23/69	14.0	29	---	---	---	40	30	---	---	---	280	74	1010	---	---	---	---	205	900	11.4	---	---	---	---	---	---	---	---	---	---	---	---
West Fork of Rock Creek:																																		
near headwaters	WQB	11/6/69	2.0	---	7.05	---	---	0.19	---	11.0	---	---	6.0	1.2	20	---	---	---	---	25	1.0	2.5	0.18	0.005	0.10	0.01	0.0	---	0.01	---	---	---	0.025	---
near headwaters	SRT	7/15/71	7.5	---	6.6	21	---	---	---	---	---	---	1.5	0.4	6	1.0	0.7	0.2	8	6	1.0	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near headwaters	SRT	9/22/71	---	11	7.0	33	---	---	---	---	---	---	3.0	0.8	11	0.9	0.9	0.1	15	12	0.4	1.0	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near mouth	WQB	11/6/69	3.5	---	7.15	---	---	0.22	---	10.0	---	---	6.0	3.0	28	---	---	---	---	33	1.0	2.5	0.20	0.006	0.09	0.0	0.0	---	0.02	---	---	---	0.02	---
near mouth	SRT	9/22/71	---	16	7.2	47	---	---	---	---	---	---	3.4	1.4	14	1.7	0.8	0.2	22	18	0.8	0.6	0.0	0.0	0.05T	0.0	0.0	0.010	0.010	---	0.002	---	0.005	0.010
Rock Creek:																																		
near headwaters	WQB	11/6/69	1.0	---	7.2	---	---	0.15	---	12.0	---	---	7.0	3.0	30	---	---	---	---	33	2.0	3.8	0.10	0.005	0.09	0.0	0.0	---	0.01	---	---	---	0.03	---
near headwaters	SRT	9/22/71	5.0	30.4	7.07	61	---	---	---	---	---	---	6.2	2.2	24	1.3	1.0	0.1	31	26	1.4	0.9	0.0	0.0	0.05T	0.0	0.0	---	0.010	---	0.002	---	0.005	0.010
near Red Lodge	WQB	11/6/69	3.0	75	7.10	---	---	0.20	---	10.0	---	---	8.0	1.8	28	---	---	---	---	35	2.0	3.8	0.17	0.005	0.09	0.0	0.0	---	0.0	---	---	---	0.02	---
near Red Lodge	WQB	7/23/69	20.0	690E	7.90	---	---	5	34	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
near Red Lodge	WQB	9/23/69	17.0	230E	7.60	---	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
near Red Lodge	WQB	9/2/74	17.8	424	8.88	325	233	---	12	8.1	1.2	2640	35	5.1	108	11	---	0.5	154	132	20	1.5	---	0.08	0.03	0.28	0.03	<.01	<.01	0.01	0.007	---	<.01	<.001
Spring Creek	WQB	9/2/74	16.0	1.4	8.23	2410	1895	---	9	12.1	3.1	800	104	58	500	380	---	7.4	293	261	1053	2.5	---	3.5	0.03	0.10	0.03	<.01	0.03	---	<.001	---	---	<.001

Samples analyzed for the following constituents were less than or equal to the listed figures (mg/1): Ag--<.001; Hg--<.001; Mo--<.005; Ni--<.005; and V--<.05; Ba, Be, and Co = 0.0. Selenium concentrations in the Clarke Fork Yellowstone River ranged from 0.0 to 0.012 mg/l for six samples.

This sub-basin is somewhat unique for the Upper Yellowstone in generally having a poor to fair quality water. Three qualitites can be distinguished in the particular sub-basin: (1) a good to excellent quality water in the Rock Creek drainage, (2) an intermediate, poor to fair quality water in the mainstem Clarks Fork River, and (3) a generally poor quality water in the remaining tributaries of the river. Correlated with these quality differences are differences in geology and topography of headwaters of these streams. The Rock Creek headwaters, like that of the Stillwater River, are located in the northern portions of the Beartooth Mountains; both of these streams possess good to excellent waters. The Clarks Fork River originates on the southern side of the Beartooth Mountains in Montana but a long reach subsequently passes through a plains region in Montana and Wyoming which possibly accounts for its downstream change in quality. The remaining tributaries originate on the plains. Waters in these tributaries are similar to waters of poor quality in small streams of the Middle and Lower Yellowstone River basins which also have plains related, headwater systems (Ref. 17 and 18). With the exception of the Rock Creek drainage, surface waters in this sub-basin are characterized by having relatively high concentrations of dissolved solids, high specific conductance, and high suspended sediment.

Waters in the West Fork of Rock Creek and in the upper reaches of Rock Creek are soft with low dissolved solids and specific conductances (less than 65 micromhos). The waters are a calcium-bicarbonate type with low magnesium, sodium, potassium, sulfate, and chloride concentrations. Unique in this upper drainage are the consistently low concentrations of iron and manganese relative to those obtained for copper, zinc, chromium, and cadmium. These latter four constituents are common metals in these streams and tend to approach limiting concentrations for public water supply in some cases. This is also true for portions of the Stillwater River drainage with its similar headwaters location. In most creeks and rivers of the Yellowstone basin, iron and manganese are the most abundant metals.

Downstream in Rock Creek, the water's chemical composition changes with increases in dissolved constituents, specific conductance, calcium, sodium, bicarbonate, and sulfate. However, like most of the basin, waters remain of a calcium-bicarbonate-type with sodium and sulfate representing secondary ions. In addition, iron and manganese increase to become the prevalent metals with no marked increases in the concentrations of the remaining metals.

Upstream in the Rock Creek drainage, the low temperatures, dissolved oxygen saturations, pH range, and low turbidities are characteristic of conditions for an excellent cold water, salmonid fishery. This is consistant with the B-D_1 and A-Open-D_1 classifications of these streams (Appendix B). Downstream, higher temperatures of the creek and higher turbidities and suspended sediment concentrations are present.

The Clarks Fork Yellowstone River also has a calcium-bicarbonate-type of water; but it is distinctively different from that in Rock Creek and is of much poorer quality due to high dissolved solid concentrations and specific conductances and large suspended sediment loads.

The river is non-saline but is typically hard varying longitudinally downstream from moderately hard to very hard and ranging with flow (Ref. 15). There is a distinct downstream increase in various dissolved constituents from the river's entry into Montana to its confluence with the Yellowstone River near Laurel. In addition, suspended sediment concentrations increase through this reach. Increases in both of these factors are due at least in part to the input of inferior water from tributaries in the region such as Silvertip Creek and Bluewater Creek.

Water in the upstream reach of the Clarks Fork is of fair quality but is definitely of poorer quality than that in the other sub-basins of the Upper Yellowstone. Bicarbonate is the predominant ion with calcium and sulfate in roughly equal amounts. This water can be classified as moderately hard to hard. Magnesium, sodium, and chloride are minor constituents. Downstream, total hardness (primarily due to calcium) and all common constituents increase in concentration, but this increase is more pronounced in sodium and in sulfate with these components becoming proportionately more important. Waters of the lower reaches of the Clarks Fork can be classified as ranging from moderately hard to hard depending upon discharge. In addition, iron and particularly nitrate concentrations increase downstream. As a result, nitrate concentrations in the lower river are much higher than those in the other streams of the Upper Yellowstone River basin and are higher than concentrations obtained from most other streams in the Yellowstone basin. These factors coupled with the increases in turbidity and suspended sediment indicate a degradation in water quality towards the stream mouth. Quality of water in these downstream reaches therefore is poor to fair depending upon flows. At high flows dissolved solids concentrations are lowest with suspended sediment highest.

In general, the major factor detracting from water quality in the Clarks Fork Yellowstone River is the sediment load which can approach and exceed 27,000 tons per day at high flows. A part of this sediment problem, however, is due to natural causes and normal geological erosion. On July 24, 1806, Captain Billy Clark of the Lewis and Clark Expedition noted in his diary that the " . . . water (of the Clarks Fork) is of a light muddy color and much colder than that of the Yellowstone." This latter aspect is apparently not the case today since average temperature differences of only 1.5°C and 2.3°C were obtained between the Yellowstone and the Clarks Fork for July and August of 1972.

With the exception of iron, metal concentrations in the Clarks Fork Yellowstone River were generally low in all samples. However, iron in several of the samples from the Lower Clarks Fork exceeded the recommended levels for drinking water (Table 9). Nitrate concentrations, although relatively high in this stream are well below the established standards for drinking water; however, concentrations of this nutrient in the Clarks Fork River and its plains tributaries are at levels generally considered to indicate eutrophic conditions. Studies have indicated that excessive growths of aquatic plants often occur in waters where nitrate (NO_3) values exceed 1.5 mg/l (Ref. 19 and 20) In addition, total phosphate concentrations in excess of 0.15 mg/l (as PO_4) along with appropriate available nitrogen levels are conducive to noxious plant growths (Ref. 7). Several samples from the Lower Clarks Fork Yellowstone River and tributaries (excepting the Rock Creek drainage) had phosphorus and nitrogen concentrations in excess of 0.15 mg/l (PO_4) and 1.5 mg/l (NO_2) respectively. In the remaining streams of the Upper Yellowstone River basin, either nitrate or phosphate, or, more commonly, both of these constituents were in concentrations considered to be non-eutrophic.

Dissolved solids in the Clarks Fork occasionally exceeded the desired concentration for public supply (Table 9). None of the common constituents in the river was greater than the suggested maximum limits for human consumption or for stock water although sulfate concentrations were often greater than desirable for public supply, especially in the lower reach. In a few cases, sulfate values were in excess of that deemed permissible for drinking water. In addition, turbidities at high flows primarily in the lower reach can also exceed the minimum levels deemed suitable for this parameter in public supplies. The Environmental Protection Agency suggests that waters with suspended sediment concentrations in excess of 80 mg/l ". . . are unlikely to support good freshwater fisheries, although fisheries may sometimes be found at lower concentrations within this range . . ." (Ref. 7 and 21). Suspended sediment concentrations in excess of 80 mg/l were consistently found in the Clarks Fork during all months with concentrations in excess of 300 mg/l commonly found from late March through July.

Dissolved oxygen concentrations in the Clarks Fork were generally near saturation and varied with temperature rather than as a result of organic pollution. The absence of extensive organic pollution in the river is confirmed by the low BOD's that were obtained from the river under all flow regimes (Table 13). Variable counts of fecal coliforms were obtained from the river samples (from 11 to 2000 colonies per 100 ml), but these are not in violation of any bacteriological standards, nor are they indicative of sewage pollution. The pH's of samples from the Clarks Fork Yellowstone River were not extreme, but rather were representative (typically between 7.5 and 8.5) of a natural pH range given the associated alkalinities. In the upper reaches, temperatures ranged from near 0.0°C to, but not exceeding, 20°C; this along with dissolved oxygen saturations and the river's pH range are in accord with the $B\text{-}D_1$ classification of its upper reach (Appendix B). In the lower reach, temperature maximums are found to be greater than 20°C approaching 23°C, consistent with a $B\text{-}D_2$ designation; this implies that the waters are suitable only for the marginal propagation of salmonid fishes. In all reaches of the Clarks Fork, suspendes sediment levels undoubtedly detract from the value of the river as a salmonid or non-salmonid fishery.

Excluding the Rock Creek drainage and Fisher Creek near the Clarks Fork headwaters, and with the exception of samples obtained from certain saline ponds in Stillwater County (related to the agricultural problem of saline seep), the smaller streams in the Clarks Fork Yellowstone River sub-basin possess the poorest quality of water of any surface water in the Upper Yellowstone River basin. The quality of water in Fisher Creek is equal to that in the West Fork of Rock Creek which indicates an excellent quality in the headwaters region of the Clarks Fork River. The river is subsequently degraded prior to reaching the Yellowstone. A part of this degradation is undoubtedly related to the input of inferior water from its lowland tributaries. There is a considerable variation in the quality of water in these lowland streams, varying from an extremely poor quality as found in Silvertip Creek to the poor, but somewhat better quality of water in Big Sand Coulee and Cottonwood Creek; an intermediate quality of water is found in Bluewater Creek (Table 13). Generally, these waters are somewhat saline and quite hard with high turbidities and suspended sediments. A variety of water quality standards and criteria are violated by most of these streams.

Silvertip Creek generally typifies the extreme case of poor water quality in these lowland tributaries. In contrast to the typical calcium-bicarbonate type of water, streams are sodium-sulfate in nature. Chloride concentrations are also quite high in roughly equal concentrations with calcium and bicarbonate. Magnesium and potassium are in lower concentrations but are also important components of the stream. Potassium concentrations in Silvertip Creek are the highest of any stream in the Yellowstone basin. Fluoride, nitrate, and boron values are high in relation to other waters of the basin with the former constituent potentially approaching the minimum levels prescribed for drinking water. Concentrations of sodium, sulfate, chloride, manganese, and boron generally exceed the minimum values considered permissible for public supply and stock water.

The waters of Silvertip Creek are very hard and slightly to moderately saline (Ref. 15) with dissolved solid concentrations in excess of many of the criteria and standards that have been established for various water uses (including irrigation). Specific conductances typically exceed 2000 micromhos and often approach 7000 micromhos which is near the lower range of values prescribing a saline seep problem. In addition, suspended sediments are markedly high ranging from 320 mg/1 at low flows to 40,000 mg/1 at high flows; this aspect also precludes many water uses. Such high sediment concentrations in the various lowland tributary streams, as illustrated by Silvertip Creek, probably account for the high sediment loads of the Clarks Fork River that are gradually increased in its downstream reaches. These sediment problems coupled with warm summer temperatures of these tributaries (near 22°C) are not in accord with the state's current $B\text{-}D_1$ classification of these streams (Appendix B) which indicates a capability of supporting a viable salmonid, cold water fishery.

Flows of the Yellowstone River in the upper basin are relatively small in comparison to downstream discharges; mean yearly discharge ranges from 3100 to 6900 cfs in contrast to flows of 11,340 and 13,030 cfs in downstream sections near Miles City and Sidney. With such lower flows in upstream reaches, the tributary streams in these regions have a greater potential for influencing the quality of water in the mainstem due to the smaller quantity of dilution water. Fortunately, most tributary streams in the Upper Yellowstone basin have a good quality of water. The Clarks Fork is the largest tributary of the mainstem in the Upper Yellowstone with a mean yearly flow of 1160 cfs. With its relatively high flows and high dissolved solids and suspended sediment concentrations, the Clarks Fork has a marked effect upon the Yellowstone River with a general degradation of water quality in the mainstem below the confluence of the two streams.

<u>Yellowstone River Sub-basins -- Confluence of Bridger Creek to the Confluence of Pryor Creek</u>

This region of the Upper Yellowstone River basin consists of two sub-basins (Ref. 3); the major stream in this area is the Yellowstone River with various small tributary creeks. These tributaries are much smaller in number than those in the sub-basin above Bridger Creek and generally have smaller flows; many are intermittent. As a result, these streams were not extensively sampled. Two such streams, Duck Creek and Canyon Creek (Table 14), were sampled and provide examples of the type of water in this segment.

The chemical composition of these streams differ from the Yellowstone River and tend to approach a sodium-sulfate-type water with calcium and bicarbonate present as important components. These waters are hard to moderately hard and can be slightly saline. Metals concentrations, particularly iron and manganese, and nitrate can be relatively high. Low BOD's and high dissolved oxygen concentrations indicate an absence of organic and municipal pollution. Such creeks have a poor to fair quality of water and are definitely of worse quality than the Yellowstone River. Although such streams individually have too small a flow to cause a noticeable load on the Yellowstone mainstem, downstream increases in the Yellowstone no doubt results at least in part to the successive and cumulative input of these tributaries. The creeks in these sub-basins are similar to the lowland tributaries of the Clarks Fork River. Data from the saline ponds in Table 14 present the extreme of chemical concentration and composition that can be ultimately gained in these lowland waters (in essence a brine).

The USGS maintains flow and/or water quality monitoring sites on the Yellowstone River in this sub-basin near Laurel, Billings, and Huntley. The chemical composition of water in this lower reach of the Yellowstone River is generally similar to that described for the upper segment. The major change in the water is a downstream increase in dissolved constituents. However, the quality of water remains quite good. This increase is illustrated in Table 15 which presents flow-classified, mean values of common ions and specific conductances for low and high flow conditions at major sites on the Yellowstone River. Table 15 also illustrates the wide variations in dissolved concentrations that can occur in response to changes in flow. This illustrates

Table 14

Typical Chemical Analyses of Water in the Yellowstone River Sub-basins—Confluence of Bridger Creek to the Confluence of Pryor Creek (43QJ and 43Q)

Sampling Site	Data Source	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Yellowstone River Mainstem																																		
near Columbus	WQB	10/2/74	---	4100E	8.30	286	219	---	<1	10.1	---	---	29	8.7	108	15	---	0.6	129	106	31	5.5	---	0.03	0.03	0.15	<.01	<.01	<.01	<.01	0.009	0.12	<.01	<.001
above Clarks Fork	WQB	9/2/74	14.7	3300E	8.48	255	199	---	3.3	9.4	2.0	138	18.0	13.4	100	14.5	---	0.6	117	97	29	3.5	---	0.07	0.03	0.15	0.03	0.002	<.004	<.01	0.006	---	<.01	<.001
above Clarks Fork	WQB	11/19/74	4.3	3800E	8.50	324	247	---	---	12.1	3.1	665	32	9.3	118	22	---	0.9	134	115	39	7.8	---	0.17	0.15	0.06	<.01	<.01	<.01	<.01	0.001	---	<.01	<.001
near Laurel	WQB	3/13/67	0.6	2180E	7.5	---	280	<23	---	---	---	---	39	9	---	56*	---	---	177	---	88	13	0.8	0.31	0.20	0.42	---	---	---	---	---	---	---	---
near Laurel	WQB	3/9/67	14.0	3520E	7.5	---	220	23	---	---	---	---	31	9	---	41*	---	---	165	---	48	12	0.7	0.12	0.14	1.10	---	---	---	---	---	---	---	---
near Laurel	WQB	6/15/67	11.8	35100E	7.4	---	140	280	---	---	---	---	24	4	---	31*	---	---	128	---	25	4	0.1	1.00	---	0.40	---	---	---	---	---	---	---	---
near Laurel	WQB	8/14/67	20.2	6760E	7.6	---	160	<25	---	---	---	---	24	4	---	33*	---	---	119	---	38	8	0.6	0.31	0.0	0.24	---	---	---	---	---	---	---	---
near Laurel	WQB	10/9/67	12.9	5800E	7.5	---	196	<25	---	---	---	---	28	20	---	20*	---	---	149	---	57	10	0.6	0.13	0.0	0.14	---	---	---	---	---	---	---	---
near Laurel	WQB	12/11/67	0.0	3550E	7.5	---	300	<25	---	---	---	---	34	12	---	42*	---	---	165	---	73	11	0.6	0.84	---	0.18	---	---	---	---	---	---	---	---
near Laurel	WQB	2/14/68	---	3050E	7.5	---	240	0	---	---	---	---	30	8	---	46*	---	---	149	---	75	5	0.6	0.46	0.0	0.07	---	---	---	---	---	---	---	---
near Laurel	WQB	4/12/68	6.2	3620E	7.5	---	300	6	---	---	---	---	36	16	---	60*	---	---	195	---	101	12	0.22	0.30	0.0	0.0	---	---	---	---	---	---	---	---
near Laurel	WQB	6/14/68	10.6	39700E	---	---	160	170	---	---	---	---	8	20	---	9*	---	---	92	---	41	4	0.16	0.55	0.0	0.30	---	---	---	---	---	---	---	---
near Laurel	WQB	7/12/68	15.4	24500E	8.3	---	110	40	---	---	---	---	15	5	---	15*	---	---	36	---	23	5	0.4	0.5	0.0	0.5	---	---	---	---	---	---	---	---
near Laurel	WQB	9/12/68	15.7	6300E	7.6	---	244	3	---	---	---	---	38	16	---	30*	---	---	149	---	82	9	0.56	4.2	0.0	0.0	---	---	---	---	---	---	---	---
near Laurel	USGS	7/24/69	20.0	10800	8.2	305	182	13	---	8.0	1.5	---	---	---	101	---	---	---	---	100	45	---	---	0.1	0.0	---	---	---	---	---	---	---	---	---
near Laurel	USGS	8/28/69*	18.0	3600	8.2	360	236	6	---	8.2	1.2	---	---	---	134	23	3.1	---	---	141	54	---	0.06	0.0	0.03	0.12	0.018	0.021	0.002	0.0	0.007	0.030	0.0	0.0
near Laurel	USGS	9/23/69	12.0	4100	8.3	425	268	14	---	9.4	2.4	---	---	---	170	---	---	---	---	159	68	---	---	0.6	0.34	---	---	---	---	---	---	---	---	---
near Laurel	USGS	12/16/69*	0.5	3260	8.2	240	207	4	---	13.0	1.7	---	---	---	159	29	3.7	---	---	186	65	---	0.5	0.89	0.0	0.112	0.009	0.027	0.024	0.0	0.010	0.504	0.0	0.0
near Laurel	USGS	5/19/70*	12.5	17400	7.8	490	197	300	---	8.0	5.2	---	---	---	114	19	2.1	---	---	102	53	---	0.4	1.77	0.09	0.057	0.011	0.008	0.012	0.0	0.007	0.213	0.0	0.0
near Laurel	USGS	6/18/70	14.0	24700	7.6	230	139	45	---	9.4	1.1	---	---	---	76	---	---	---	---	77	33	---	---	0.66	0.24	---	---	---	---	---	---	---	---	---
near Laurel	USGS	7/27/70	20.0	10500	8.0	330	181	---	---	8.8	1.5	---	25	8.8	99	21	---	---	---	---	---	---	0.1	0.31	0.28T	---	0.0	0.025	0.011	0.0	0.004	0.101	0.0	0.0
near Laurel	USGS	9/14/70	6.5	7060	7.9	430	269	---	---	11.2	1.5	27	29	15	158	---	---	---	---	---	---	4.8	---	0.97	0.06T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	12/14/70	0.0	3080	7.8	490	293	---	---	13.0	1.0	---	44	14	170	---	---	---	---	---	84	5.6	---	1.77	0.06T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	2/23/71	0.0	3200	8.1	440	294	---	---	10.2	0.8	8	47	14	180	---	---	---	---	---	76	7.2	0.7	0.89	---	---	---	---	---	---	---	---	---	---
near Laurel	USGS	4/14/71	9.5	3800	---	480	222	---	---	7.2	2.1	48	41	13	160	23	---	---	---	---	72	4.8	0.6	0.84	0.0	---	0.020	0.020	0.002	0.0	0.010	0.170	0.0	0.001
near Laurel	USGS	6/16/71	12.0	41200	---	180	90	---	---	8.0	1.0	470	12	3.3	44	---	---	---	---	---	11	1.4	---	0.18	0.91T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	7/13/71	15.5	21600	7.7	175	112	---	---	8.6	1.2	180	15	4.7	57	8.4	---	---	---	---	32	1.9	0.3	0.13	0.61T	---	0.038	0.0	0.002	0.004	0.0	0.050	0.0	0.0
near Laurel	USGS	8/12/71	22.0	8000	8.6	240	160	---	---	9.8	0.9	27	28	7.1	84	---	---	---	---	---	29	4.8	---	0.18	0.21T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	9/16/71	11.0	6000	8.2	350	218	---	---	8.0	1.6	110	32	11	130	---	---	---	---	---	52	4.6	---	0.35	0.28T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	10/20/71	7.5	5700	8.2	380	250	---	---	7.8	1.7	220	35	12	140	26	---	1.0	---	---	73	6.0	0.4	0.58	0.40T	---	0.02	0.0	0.004	0.0	0.002	0.150	0.0	0.0
near Laurel	USGS	1/17/72	0.0	2900	7.6	420	280	---	---	12.4	1.4	390	43	14	160	24	---	0.8	---	---	77	7.8	0.5	2.08	0.06T	---	0.04	0.020	0.004	0.0	0.005	0.210	0.0	0.0
near Laurel	USGS	3/21/72	9.0	5340	8.4	360	234	---	---	10.3	1.3	30	33	11	130	---	---	---	---	---	55	6.8	---	0.49	0.46T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	5/22/72	12.0	21300	7.2	170	154	---	---	8.6	2.4	1800	18	4.7	64	---	---	---	---	---	19	2.8	---	0.53	1.81T	---	---	---	---	---	---	---	---	---
near Laurel	USGS	6/22/72	14.5	25500	7.5	140	150	---	---	8.3	1.4	390	13	4.1	49	---	---	---	---	---	16	1.6	---	0.13	0.40T	---	---	---	---	---	---	---	---	---
near Laurel	WQB	9/2/74	15.5	6050	8.48	362	259	---	8.5	10.3	2.6	1800	31	11.5	125	21	---	0.8	128	111	56	7.0	---	0.14	0.03	0.21	<.01	<.01	<.01	<.01	0.010	---	<.01	<.001
near Laurel	WQB	10/2/72	---	4800E	8.40	373	280	---	---	10.9	---	---	35	12.6	139	21	---	0.8	147	122	57	5.8	---	0.08	0.31	0.24	0.06	<.01	<.01	<.01	0.016	0.17	<.01	<.001
at Billings	WQB(a)	7/22/74	21.8	2500	8.22	192	139	25	68	---	---	---	18.4	5.8	70	12	---	0.6	81	66	19	3.0	---	0.32	0.08	1.3	0.04	0.01	<.01	---	<.001	<.10	<.01	<.001
at Billings	WQB(b)	7/22/74	21.8	2500	8.30	193	149	24	70	---	---	---	19.2	5.3	70	12	---	0.6	79	65	30	3.0	---	0.28	0.07	1.3	0.04	0.01	<.01	---	<.001	0.14	<.01	<.001
at Billings	WQB(c)	7/22/74	21.9	2500	8.20	194	144	22	50	---	---	---	16.8	6.8	70	12	---	0.6	81	66	25	3.0	---	0.27	0.07	1.1	0.03	0.01	<.01	---	<.001	<.10	<.01	<.001
at Billings	WQB	3/13/67	0.0	2180	---	---	270	<25	---	---	---	---	41	13	---	39*	---	---	174	---	77	13	0.7	0.46	0.16	0.55	---	---	---	---	---	---	---	---
at Billings	WQB	5/9/67	15.7	3520	7.6	---	260	25	---	---	---	---	41	10	---	51*	---	---	177	---	89	11	0.7	0.18	0.14	1.1	---	---	---	---	---	---	---	---
at Billings	WQB	6/15/67	12.9	55100	7.4	---	160	650	---	---	---	---	31	1	---	32*	---	---	143	---	34	7	0.1	0.80	1.08	0.48	---	---	---	---	---	---	---	---
at Billings	WQB	8/14/67	---	6760	---	---	180	<25	---	---	---	---	24	6	---	38*	---	---	134	---	42	8	0.9	0.33	0.0	0.24	---	---	---	---	---	---	---	---
at Billings	WQB	10/4/67	12.9	5800	---	---	220	<25	---	---	---	---	28	15	---	32*	---	---	165	---	61	7	0.4	0.22	0.0	0.43	---	---	---	---	---	---	---	---
at Billings	WQB	12/11/67	0.0	3550	7.5	---	270	<25	---	---	---	---	34	14	---	48*	---	---	177	---	81	10	0.5	0.10	0.0	0.27	---	---	---	---	---	---	---	---
at Billings	WQB	2/14/68	0.0	3050	7.4	---	270	0	---	---	---	---	38	12	---	49*	---	---	177	---	88	11	0.6	1.00	0.0	0.10	---	---	---	---	---	---	---	---
at Billings	WQB	4/12/68	6.2	3620	7.3	---	250	13	---	---	---	---	34	6	---	55*	---	---	171	---	71	10	0.22	0.27	0.0	0.0	---	---	---	---	---	---	---	---
at Billings	WQB	6/14/68	11.8	39700	---	---	250	2000	---	---	---	---	26	5	---	42*	---	---	116	---	71	5	0.02	0.55	0.0	0.48	---	---	---	---	---	---	---	---
at Billings	WQB	7/8/68	15.7	25300	8.5	---	100	35	---	---	---	---	23	0	---	18*	---	---	85	---	22	3	0.7	0.5	0.0	0.7	---	---	---	---	---	---	---	---
at Billings	WQB	9/12/68	15.7	6300	7.6	---	188	3	---	---	---	---	40	7	---	17*	---	---	130	---	44	8	0.4	0.9	0.0	0.2	---	---	---	---	---	---	---	---
at Billings	USGS	1/25/68	---	3850	7.3	421	266	---	---	---	---	---	38	14	152	27	3.4	1.0	149	---	83	6.6	0.5	1.2	---	---	---	---	---	---	---	0.20	---	---
at Billings	USGS	6/11/68	---	33400	7.7	199	140	---	---	---	---	---	21	5.3	75	10	1.8	0.5	94	---	24	2.1	0.1	0.3	---	0.04	---	---	---	---	---	0.07	---	---
at Billings	USGS	9/6/68	---	8250	7.6	317	214	---	---	---	---	---	29	10	115	19	2.4	0.8	131	---	49	4.5	0.3	0.0	---	0.0	---	---	---	---	---	0.15	---	---
at Billings	USGS	12/4/68	---	3830	7.6	400	241	---	3	---	---	---	38	13	148	24	3.2	0.9	153	---	65	6.8	0.5	0.5	---	0.28	---	---	---	---	---	0.19	---	---
at Billings	USGS	3/27/69	---	3720	7.6	402	253	---	71	---	---	---	37	12	142	26	3.6	1.0	146	---	74	7.2	0.5	0.1	0.05	0.06	---	---	---	---	---	0.19	---	---
at Billings	USGS	6/12/69*	---	24900	7.7	177	134	---	260	---	---	---	18	5.4	68	9.5	1.8	0.5	77	---	22	2.9	0.3	0.0	---	0.11	0.0	0.040	0.0	0.014	---	0.06	0.0	0.0
at Billings	USGS	9/11/69	---	3140	7.7	457	267	---	8	---	---	---	38	16	161	30	4.1	1.0	173	---	77	6.0	0.6	1.1	0.08	0.01	0.06	0.009	0.0	0.0	---	0.20	0.0	0.0
at Billings	USGS	1/7/70	0.0	1330	7.9	602	376	---	29	---	---	---	50	20	207	40	6.1	1.2	202	---	118	9.0	0.7	2.56	0.01	0.166	---	---	---	---	---	0.326	---	---
at Billings	USGS	6/3/70	15.5	24200	7.3	225	133	---	120	---	---	---	22	6.3	81	12	1.7	0.6	94	---	27	2.4	0.3	0.04	0.04	0.05	---	0.017	0.042	0.0	---	0.18	0.0	0.0
at Billings	USGS	8/3/70	21.0	9000	8.2	276	157	---	39	---	---	---	22	8.4	89	18	2.5	0.8	108	---	39	4.3	0.5	0.04	0.04	0.017	---	---	---	---	---	0.105	---	---
at Billings	USGS	10/6/60	10.0	4930	8.2	366	241	---	9	---	---	---	38	13	150	25	3.2	0.9	156	---	67	5.9	0.5	---	---	0.0	---	0.001	---	0.0	0.007	0.120	0.0	0.0
at Billings	USGS	2/9/71	0.5	3110	7.9	392	240	---	---	---	---	---	41	11	150	26	3.5	0.9	155	---	58	6.3	0.6	0.0	---	0.110	---	---	---	---	---	---	---	---
at Billings	USGS	5/10/71	12.5	13700	8.2	225	139	---	---	---	---	---	24	7.1	89	11	3.3	0.5	104	---	22	3.6	0.3	0.89	---	0.08	---	---	---	---	---	---	---	---
at Billings	USGS	7/8/71	14.5	27000	8.0	179	108	---	250	---	---	---	15	5.2	59	10	1.7	0.6	76	---	22	3.0	0.6	0.66	---	0.04	---	---	---	---	---	0.00	---	---
at Billings	USGS	8/10/71	22.0	8890	7.5	263	166	---	---	---	---	---	24	8.3	94	16	2.4	0.7	119	---	39	3.7	0.5	0.66	---	0.02	---	---	---	---	---	---	---	---
at Billings	USGS	12/2/71	0.0	3700	8.2	398	251	---	4	---	---	---	38	13	150	24	3.1	0.9	151	---	77	6.6	0.4	0.53	---	0.01	---	---	---	---	---	0.200	---	---
at Billings	USGS	2/7/72	0.0	2970	7.7	438	290	---	---	---	---	---	44	14	170	25	3.5	0.8	170	---	87	10	0.6	2.35	---	0.04	---	---	---	---	---	---	---	---
at Billings	USGS	6/6/72	15.0	41300	7.0	118	78	---	250	---	---	---	14	3.3	49	5.0	1.3	0.4	56	---	12	1.1	0.1	0.58	---	0.08	---	---	---	---	---	---	---	---
at Billings	USGS	8/14/72	21.5	7020	7.8	304	188	---	---	---	---	---	29	10	110	19	2.5	0.8	130	---	46	4.4	0.7	0.53	---	0.09	---	---	---	---	---	---	---	---
at Billings	USGS	2/12/73	0.5	3160	7.9	429	280	---	---	---	---	---	46	13	170	25	3.5	0.8	161	---	84	7.9	0.6	1.73	0.09	0.05	---	---	---	---	---	---	---	---
at Billings	USGS	5/4/73	10.5	8500	8.2	549	352	---	---	---	---	---	46	18	190	46	3.3	1.5	197	---	120	7.2	0.4	2.53	0.03	0.009	---	---	---	---	---	---	---	---
at Billings	USGS	6/20/73	11.5	15200	8.2	217	141	---	140	---	---	---	21	6.5	79	13	1.8	0.6	96	---	33	3.7	0.4	0.58	0.0	0.05	---	---	---	---	---	---	---	---
at Billings	USGS	9/18/73	12.0	5970	8.2	382	245	---	---	---	---	---	37	13	150	25	2.9	0.9	157	---	69	5.2	0.4	3.19	0.12	0.05	---	---	---	---	---	---	---	---
at Huntley	WQB	2/13/67	1.1	2930E	7.5	---	300	---	---	---	---	---	38	20	---	43*	---	---	180	---	100	12	0.6	0.64	---	0.42	---	---	---	---	---	---	---	---
at Huntley	WQB	3/13/67	0.6	2180E	7.5	320	320	48	---	---	---	---	41	17	---	42*	---	---	180	---	94	13	0.7	0.42	0.10	1.06	---	---	---	---	---	---	---	---
at Huntley	WQB	5/9/67	15.7	3520E	7.5	---	320	102	---	---	---	---	53	8	---	55*	---	---	207	---	92	12	0.6	0.20	0.14	2.3	---	---	---	---	---	---	---	---
at Huntley	WQB	6/15/67	14.0	55100E	---	---	176	920	---	---	---	---	31	6	---	39*	---	---	162	---	41	6	0.2	0.93	1.24	0.42	---	---	---	---	---	---	---	---
at Huntley	WQB	8/14/67	21.8	6760E	---	---	206	<25	---	---	---	---	24	15	---	33*	---	---	140	---	58	11	0.7	0.35	0.0	0.16	---	---	---	---	---	---	---	---
at Huntley	WQB	10/9/67	17.9	5800E	7.5	---	250	<25	---	---	---	---	34	9	---	72*	---	---	183	---	69	9	0.5	0.4	0.0	0.61	---	---	---	---	---	---	---	---
at Huntley	WQB	12/11/67	0.0	3550E	---	---	284	<25	---	---	---	---	48	8	---	50*	---	---	187	---	90	10	0.5	0.97	0.0	0.05	---	---	---	---	---	---	---	---
at Huntley	WQB	2/14/68	---	3050E	---	---	296	5	---	---	---	---	40	14	---	49*	---	---	180	---	95	11	0.6	0.93	0.0	0.10	---	---	---	---	---	---	---	---
at Huntley	WQB	4/12/68	6.2	3620E	7.5	---	266	6	---	---	---	---	44	11	---	44*	---	---	177	---	79	9	0.28	0.32	0.0	0.0	---	---	---	---	---	---	---	---
at Huntley	WQB	5/17/68	15.7	7900E	7.6	---	220	5	---	---	---	---	36	7	---	39*	---	---	152	---	63	8	0.26	0.5	0.0	0.09	---	---	---	---	---	---	---	---
at Huntley	WQB	6/14/68	12.9	39700E	---	---	210	3000	---	---	---	---	24	7	---	47*	---	---	122	---	89	3	0.02	0.8	---	0.75	---	---	---	---	---	---	---	---
at Huntley	WQB	7/8/68	16.8	25300E	8.4	---	120	35	---	---	---	---	23	0	---	10*	---	---	85	---	18	4	0.2	1.7	0.0	0.0	---	---	---	---	---	---	---	---
at Huntley	WQB	9/9/68	16.8	7120E	---	---	214	7	---	---	---	---	36	18	---	15*	---	---	142	---	61	9	0.38	0.8	0.0	0.4	---	---	---	---	---	---	---	---
at Huntley	USGS	7/14/72	18.0	14400	7.6	200	140	---	---	7.8	1.8	140	19	6.9	76	13	---	0.7	---	71	33	3.0	0.5	0.17	0.03	---	---	---	---	---	---	---	---	---
at Huntley	USGS	8/8/72	21.5	8020	8.2	320	230	---	---	8.0	1.7	2000	---	9.6	67	19	---	1.0	---	98	56	5.2	0.6	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	9/8/72	16.5	7490	8.3	360	244	---	---	7.4	1.9	1300	34	12	130	22	---	0.8	---	116	68	5.2	0.5	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	12/14/72	0.0	2700	7.5	540	324	---	---	8.2	2.3	2300	52	18	204	35	---	1.1	---	166	110	9.0	0.6	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	1/16/73	1.5	4600	7.6	440	278	---	---	10.7	2.5	38	40	13	150	27	---	0.9	---	120	73	7.5	0.6	1.64	0.06	---	---	---	---	---	---	---	---	---
at Huntley	USGS	3/15/73	6.0	3000	8.5	470	318	---	---	10.9	2.1	45	42	15	170	33	---	1.1	---	134	99	7.7	0.6	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	5/10/73	11.0	[illegible]	8.3	480	297	---	---	9.5	2.6	500	43	15	170	35	---	1.2	---	152	93	5.7	0.3	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	6/14/73	14.5	26000	6.9	160	104	---	---	7.6	1.1	330	15	4.7	57	9.3	---	0.5	---	50	22	1.5	0.2	---	---	---	---	---	---	---	---	---	---	---
at Huntley	USGS	7/18/73	21.0	7200	8.2	320	204	---	---	8.8	2.2	120	28	10	110	20	---	0.8	---	97	54	5.1	0.4	0.22	0.03	---	---	---	---	---	---	---	---	---
at Huntley	USGS	8/15/73	24.5	4200	8.6	445	257	---	---	8.8	1.9	240	37	15	150	30	---	1.1	---	129	85	6.0	0.4	0.49	0.06	---	---	---	---	---	---	---	---	---
at Huntley	WQB	4/25/74	14.0	5760	7.90	371	276	28	81	8.9	2.6	24	37	11.0	136	22	---	0.8	137	112	64	4.6	---	0.67	0.14	1.5	0.10	0.01	<.01	---	---	---	---	<.001
at Huntley	WQB	10/2/74	---	4800E	8.24	424	316	---	---	12.0	---	---	37	15.3	156	26	2.8	0.9	148	127	76	6.7	0.38	0.31	0.03	0.24	0.05	[illegible]	<.01	<.01	---	0.19	<.01	<.001
at Huntley	WQB	11/19/74	4.8	4300E	8.30	505	387	---	---	---	---	---	44	17.8	183	35	---	1.1	174	143	106	9.2	---	0.75	0.18	0.29	0.04	<.01	<.01	<.01	0.001	---	<.01	<.001
at Huntley	WQB	12/13/74	0.5	3500E	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.4	0.12T	---	---	---	---	---	---	---	---	---
Tributaries and Miscellaneous Ponds																																		
near Wheat Basin	WQB	10/2/74	12.5	---	8.90	37100	47328	---	---	---	---	---	650	2400	11504	10100	---	41.0	567	645	31883	1610	---	8.9	---	0.33	0.04	[illegible]	0.11	<.01	0.007	---	<.01	---
north of Columbus	WQB	10/2/74	12.0	---	9.90	50880	72123	---	---	---	---	---	900	5600	25302	13760	---	37.5	49	240	48545	3200	---	9.3	---	3.8	0.02	0.07	0.15	<.01	0.038	---	<.01	---
Duck Creek	WQB	9/2/74	17.1	1.6	8.57	2903	2298	---	1.5	12.1	2.5	3450	164	95	800	350	---	6.0	283	236	1358	6.0	---	0.10	<.03	---	<.01	<.01	0.01	---	<.001	---	---	0.001
Canyon Creek	WQB	10/2/74	---	260	7.80	494	366	---	73	10.9	---	---	40	17.6	172	35	---	1.2	156	128	109	7.7	---	0.17	0.18	1.1	0.04	<.01	<.01	<.01	0.01	0.56	<.01	<.001

Samples analyzed for the following constituents were generally less than or equal to the listed figures (mg/1): Ag--<.002; Al--<.2, Ba--<.001; Be--<.01, Co--<.01; Hg [illegible], Ni--<.1 Ai--<.003; V--<.05. Lithium and selenium were found in the following ranges for five and eleven

Table 15

Mean high flow and low flow values of common water quality parameters for several water quality sites in the Yellowstone River Basin (compiled from United States Geological Survey *Water Quality Records*, 1969-1972). Values are in mg/l.

Stream & Site	Calcium		Magnesium		Sodium		Bicarbonate		Sulfate		Chloride		Spec. Cond.	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
Yellowstone R. nr Livingston	9.3	25.7	2.7	7.7	5.2	21.3	49.0	116.0	8.7	33.0	2.0	11.0	96	295
Yellowstone R. nr Laurel	13.3	41.8	4.4	13.5	8.4	25.5	----	------	19.7	84.3	1.6	6.7	165	465
Yellowstone R. nr Billings	18.0	45.0	5.2	14.0	10.0	29.0	85.0	175.0	23.0	91.0	2.4	7.7	188	463

the general case for large streams such as the Clarks Fork, Yellowstone, and Stillwater Rivers wherein ionic concentrations decrease with increasing flows. However, this relationship is not directly proportional, i.e., concentrations decrease less rapidly than flows increase; as a result, similar to the case for suspended sediments, the net effect of enhanced flows is an increase in the loading of dissolved materials in a river. Thus the load of dissolved solids is generally greatest at periods of low concentrations but high discharge.

One major change in the Yellowstone River from Livingston to Huntley is a general increase in the maximum, summer temperatures of the stream (Table 14). This is correlated with the general change of the river from a cold water fishery upstream to a warm water fishery in its lower reaches. Table 16 presents a monthly summary of mean monthly specific conductances and temperatures in the Yellowstone River at Livingston and at Billings. This data also illustrates the downstream increase in temperature during the summer period.

The consistent downstream increases in specific conductances (Table 16) are also indicative of the general degradation of water quality in the Yellowstone River through the Upper Yellowstone River basin. Specific conductance varies by month and season with higher values obtained during the cold winter months. Ignoring the aspect of suspended sediment, water quality in the Yellowstone River is apparently best upstream and at high flow periods. However, suspended sediments, which increase with flow, potentially detract from this quality. Sediment data for the Clarks Fork in Table 16 aptly illustrates this flow related increase in suspended materials for a major stream of the basin; concentrations are greatest during the spring period of increased runoff from snowmelt in the sub-basin. In addition, the wide discrepancies between the various major streams in the upper basin relative to any potential sediment loading of the Yellowstone are also illustrated by the data in this table; the Clarks Fork River has by far a greater effect of this nature than either the Boulder or the Stillwater River. Given the quality of water in the Clarks Fork and its flow regime, a similar conclusion can be drawn for dissolved solids. Various inputs of dissolved solids into the upper reaches of the Yellowstone River from its many surface tributary sources and from groundwater can be ranked in importance as follows (as increases in dissolved solid concentrations through various reaches of the Yellowstone River:

1.	Laurel to Huntley (the Billings area)	57 mg/l
2.	Corwin Springs to Emigrant (small tributaries)	41 mg/l
3.	Columbus to Laurel (Clarks Fork)	40 mg/l
4.	Livingston to Springdale (Shields River)	20 mg/l
5.	Springdale to Greycliff (Boulder River)	10 mg/l
6.	Greycliff to Columbus (Stillwater River)	2 mg/l
7.	Emigrant to Livingston (small tributaries)	-5 mg/l
	Upper Basin	165 mg/l
	Middle Basin	199 mg/l
	Lower Basin	2 mg/l

Table 16

Monthly mean water temperatures (^{o}C) and specific conductances obtained at United States Geological Survey sites on the Yellowstone River near Livingston and Billings, and mean monthly suspended sediment concentrations (mg/l) for Boulder River near Contact, Stillwater River near Nye, and Clarks Fork Yellowstone at Edgar. Temperature and specific conductance means calculated for water years 1970-1973; sediment means for Boulder and Stillwater, water year 1972, for Clarks Fork Yellowstone, July 1972-June 1973.

SITE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
Temperature												
Livingston	8.5	5.0	2.0	2.0	3.5	6.0	8.5	11.0	12.0	17.0	18.5	13.0
Billings	7.5	3.5	1.0	0.5	0.5	5.0	8.0	12.0	11.0	17.5	20.0	14.5
Specific Conductance												
Livingston	234	247	278	290	284	282	272	170	108	145	191	218
Billings	390	400	445	451	425	446	432	307	159	212	324	358
Suspended Sediment												
Boulder	2.5	3.5	4.0	3.0	2.5	2.5	2.0	9.0	42	5.5	3.5	2.5
Stillwater	1.5	2.0	3.0	3.0	3.5	3.0	2.5	14	18	4.0	3.0	2.0
Clarks Fork Yellowstone	105	69	96	98	86	219	1050	1130	427	147	302	112

This data was collected during October 1-2, 1974. Increases in dissolved solids through the Upper Yellowstone are only slightly less than those through the middle segment and much greater than such increases through the lower reach. Of the major upstream tributaries, the Clarks Fork had by far the greatest effect followed by the Shields River.

Water Quality of Selected Point Source Discharges

Chemical data for samples collected from various point source discharges in the Upper Yellowstone River basin is shown in Table 17. The nature of these wastewaters generally reflects the source of water for the specific municipality. An apparent effect on the water in passing through the community is the increase in dissolved constituents. In some cases, there is a significant increase in sodium, sulfate, and bicarbonate concentrations. In addition, nitrate and phosphate concentrations are relatively high in these effluents in comparison to the streams as are the effluent BOD's and fecal coliform counts. Although concentrations of substances in these wastewaters are generally high in comparison to their receiving waters, the flows from these waste discharges are generally so small that there is no measurable amount of increased loading to the streams. An exception to this may occur in Rock Creek at low flows from the combined effects of the Red Lodge, Roberts, and Joliet effluents.

High fecal coliform counts were occasionally obtained from some of the streams in the Upper Yellowstone Basin. In many cases however, such high counts were not derived from municipal sewage lagoon effluents nor from wastewater treatment plants. As examples, Billman and Cinnebar Creeks (Table 10) and the West Fork of Rock Creek (Table 13) do not receive discharges from such facilities. High fecals in these streams are primarily due to animal origins and to runoff from agricultural land. The same is probably true for the Shields River (Table 11); towns along this stream have septic tanks which are not located in close proximity to the river. High fecal coliform concentrations in the Clarks Fork River (Table 11) probably stem in the main from the numerous and small confined feeding areas that occur along the stream. Similar to the case of Rock Creek however, discharges emanating from the few small municipalities that occur along the river (Table 3) could cumulatively increase fecal counts downstream, e.g., at Laurel. The only case where high fecal concentrations can be definitely ascribed to human sources is the Yellowstone mainstem (possibly at Laurel but especially downstream from Laurel to Huntley, Table 14). In this case, various sewage lagoon effluents of small volume discharge into the river above Laurel and major wastewater discharges occur in the Billings area (Table 3). The Billings waste load allocation investigation is currently considering the fecal coliform problem in this reach of the river. (See Table 18 for a summary of water pollution problems in the basin.)

Effect of Non-Point Sources on Streams

Some evidence is available for the effect of non-point sources on the stream of the basin. The influence of acid mine drainage on the upper Stillwater River is readily available in the water quality data for this reach of the stream (e.g., the depressed pH values and zero alkalinities listed in Table 12--Stillwater River near headwaters). Without adequate safeguards, similar problems could develop with the John Mansville mining development in the Stillwater drainage along with increased metals and nutrient concentrations.

Mining activity could also increase turbidities and suspended sediments in the streams. This is possibly the case for the East Boulder River although such problems are quite minor in this stream (Table 11) and could also be caused by poor land management as well as by natural sources; the overall quality of water in the East Boulder River is inferior to that of its sister tributaries. High turbidity and suspended sediment in the Clarks Fork River however is much more severe (Table 13) and is not due to mining. This problem is due in part to natural features in its drainage (e.g., readily erodable soils) that are accentuated by poor agricultural practices (e.g., overgrazing, removal of riparian vegetation, cultivation of fragile soils, and so on). The Mid-Yellowstone Areawide Planning Organization (a "208 program") is devoting a great deal of attention to resolving the sediment problems in the Clarks Fork Yellowstone River. Similar problems on the Shields River have been rectified to some extent in recent years.

Evidence of other non-point problems is also present in the Upper Yellowstone River Basin. The occurrence of high fecal coliform concentrations in certain streams and at certain times, as derived from agriculture, has been discussed previously. In addition, high fecal counts can also stem from groundwater via septic tank contamination. Homes in the unincorporated Heights area east of Billings utilize septic tanks for sewage disposal. Groundwater emerges from the sandstone bluffs (Rimrocks) near the Yellowstone River (e.g., the "Weeping Walls") potentially carrying some sewage with it that could then enter the stream. This problem has not yet been extensively investigated and no direct effect on the Yellowstone has been observed or documented. However, a part of the high fecal coliform load in the river near Billings could be derived from this source (Table 14, approaching $4\frac{1}{2}$ billion cells per second). A similar problem of this kind, although of a smaller magnitude, could also exist in relation to the Lockwood development near Billings. Since extensive tracts are currently being developed for housing in the Huntley-Worden region east of Billings, similar problems derived from these unincorporated areas could develop throughout the lower portion of the Yellowstone River in the basin.

Groundwater pollution of a different kind that affects the Yellowstone River occurs at Laurel and Livingston. In both cities petroleum wastes have seeped into the ground--in the former derived from an oil refinery and in the latter derived from the refueling of trains. These wastes have become evident in storm sewers and ditches concomitant with high water tables and have been observed to enter the Yellowstone River. The Laurel problem will be largely resolved at the urging of the Environmental Protection Agency through the construction, in 1976, of a relay sewer in the refinery area. No action has been directed to the problem at Livingston at the present time.

Two other groundwater-surface water problems have also developed in the basin. These problems are somewhat similar. One occurs at Columbus which in the past had a potassium dichromate mill. The infiltration and percolation of water through waste piles resulted in groundwater with high metal concentrations (particularly chromium). The surfacing of this groundwater provided symptoms similar to that of saline seep in leaving an "orange crust" on lands in the area. Anaconda Copper Company has attempted to rectify the situation by neutralizing the material; the success of this effort is not known. The City of Columbus now owns most of the land affected by this "seep" so the ultimate resolution of the problem remains a question. High chromium concentrations are not now evident in the Yellowstone River below Columbus (Table 14); however, the potential of this affected groundwater for influencing surface waters in the eastern portion of the basin cannot be ignored.

The second problem of this type relates to the actual "saline seep" phenomenon that occurs in the basin, particularly in Stillwater County (23,000 acres, Ref. 22). This phenomenon and its effect on water quality has been fully described in a report prepared by the Montana Water Quality Bureau (Ref. 23). The potential for such seeps in affecting surface water quality is illustrated in Table 14.

Silvertip Creek, a prairie stream, is somewhat distinctive for the Upper Yellowstone Basin in having a poor quality of water. It has both high dissolved and high suspended solids concentrations (Table 13). This stream was intermittent in nature until the development of the Elk Basin Oil Field; it is now perennial due to discharges from this development. The high suspended sediments in the stream are due primarily to the fragile soils of the area coupled with poor land-use practices; however this problem is possibly enhanced as a result of the induced pereniality of the creek. In turn, high dissolved solid concentrations in the stream are also probably due to natural sources to some extent; this is typical of prairie streams. However, salt levels are probably enhanced to some degree by the "salty" discharges that enter the stream from the oil field. The actual discharge of oil wastes into Silvertip Creek has been largely corrected in recent years. This was once a major water quality problem in the basin.

See Table 18 for a summary of water pollution problems in the basin.

Table 17

Chemical Analyses of Wastewater Collected by the Montana Water Quality Bureau from Various Effluents in the Upper Yellowstone River Basin

Sampling Site	Date	Temp	Flow	pH	SC	DS	Turb	TSS	DO	BOD	FC	Ca	Mg	TH	Na	K
Municipal Sewage Lagoons and Treatment Plants																
Gardiner	11/18/74	3.1	----	7.50	681	488	----	----	9.8	42	2750	50	24	224	50	---
Livingston	10/3/73	----	3.4	7.10	670	511	----	76	---	---	$7x10^6$	59	25	250	40	---
Livingston	10/1/74	----	3.87	7.20	----	----	----	48	---	54	$7x10^6$	---	----	---	-----	---
Big Timber	10/3/73	----	0.0	7.20	540	380	----	24	---	---	-----	50	21	211	25	---
Big Timber	10/1/74	----	0.45	6.80	400	251	----	8	---	28	$1x10^6$	26	17	136	24	---
Columbus	10/3/73	----	0.01	7.50	1770	1362	----	28	---	---	-----	49	41	291	300	---
Columbus	10/2/74	----	0.03	8.30	1781	1281	----	35	---	77	$2x10^4$	45	28	270	288	---
Laurel	7/31/74	----	2.69	7.20	1997	1389	21	60	---	28	$3x10^5$	116	81	625	180	8
Red Lodge	9/27/73	----	1.39	7.30	180	119	----	30	---	80	$<10^3$	16	5.3	62	70	---
Roberts	9/27/73	----	0.31	7.20	328	242	----	30	---	142	$2x10^3$	35	13.1	142	9.3	---
Joliet	9/26/73	- -	0.12	7.30	1105	883	----	24	---	76	96000	71	63	435	70	---
Other Sources																
Jardine Mine	6/5/73	----	----	----	----	----	----	-- -	---	---	-----	---	----	---	-----	---
Burlington Northern, Livingston	10/1/74	----	----	7.20	1295	963	----	----	---	---	-----	22	10.8	99	250	---
Burlington Northern, Livingston	11/18/74	18.7	----	7.20	862	565	----	----	6.0	>6	-----	47	12.4	169	110	---
Big Timber Fish Hatchery	10/31/74	----	----	8.00	485	392	----	----	---	---	-----	58	17.9	218	14	8.0
Corette Generating Plant, Billings	7/22/74	27.6	----	9.20	272	161	0.5	2.0	7.6	---	-----	30	4.4	92	12	---

Sampling Site	Date	SAR	HCO_3	TA	SO_4	Cl	F	NO_3	PO_4	Fe	Mn	Zn	Cu	Pb	As	B	Cr	Cd
Municipal Sewage Lagoons and Treatment Plants																		
Gardiner	11/18/74	1.5	212	174	101	34	----	15	2.9	0.07	0.01	0.02	<.01	<.01	0.005	----	<.01	<.001
Livingston	10/3/73	1.1	304	249	56	19	0.64	0.37	7.0	0.81	----	0.20	0.11	0.13	0.01	----	----	0.01
Livingston	10/1/74	----	---	---	---	----	----	0.22	0.05	----	----	----	----	----	-----	----	----	-----
Big Timber	10/3/73	0.7	215	176	41	14.5	0.15	0.41	13	0.13	--	0.03	0.01	0.01	<.01	----	----	<.01
Big Timber	10/1/74	0.9	133	109	34	16.1	----	0.09	0.49	0.27	0.01	<.01	0.03	<.01	0.005	0.10	<.01	<.001
Columbus	10/3/73	7.7	492	404	380	87	0.41	0.24	13	0.08	----	0.01	0.01	<.01	<.01	----	----	<.01
Columbus	10/2/74	7.6	436	358	394	79	----	0.03	0.28	0.21	0.09	<.01	0.01	<.01	0.009	0.91	<.01	<.001
Laurel	7/31/74	3.1	216	177	759	27	1.05	-----	-----	0.75	0.31	0.08	0.02	<.01	0.005	----	----	<.001
Red Lodge	9/27/73	0.4	67	55	20	2.5	0.04	0.25	0.50	0.77	----	0.18	0.02	0.01	<.01	----	----	<.01
Roberts	9/27/73	0.3	156	128	22	4.7	0.10	0.73	0.50	0.83	----	1.0	0.02	0.01	<.01	----	----	<.01
Joliet	9/26/73	1.5	525	430	133	10.5	0.33	2.7	9.0	0.60	----	0.10	0.01	0.01	<.01	----	----	<.01
Other Sources																		
Jardine Mine	6/5/73	----	---	---	---	----	----	-----	-----	0.07	----	0.02	<.01	0.02	-----	----	----	<.01
Burlington Northern, Livingston	10/1/74	11.0	323	265	309	47	----	0.09	1.2	----	----	----	----	----	-----	----	----	-----
Burlington Northern, Livingston	11/18/74	3.7	137	113	208	45	----	5.3	0.06	0.50	0.08	0.01	<.01	<.01	<.001	----	0.02	<.001
Big Timber Fish Hatchery	10/31/74	0.4	244	200	29	9.8	0.74	11	0.31	----	--	----	----	----	-----	----	----	-----
Corette Generating Plant, Billings	7/22/74	0.5	27	30	82	2.0	----	0.12	<.03	0.03	0.01	0.01	<.01	- --	<.001	0.19	<.01	<.001

Additional Parameters	Date	Be	Co	Hg	Li	Se	V
Corette Generating Plant, Billings	7/22/74	<.01	<.01	<.001	0.03	<.001	0.03

IX. BIOLOGICAL CONDITIONS

Creeks and rivers in the basin typically have cold water habitats with generally good to excellent quality of water. Biological conditions in these streams at the present time are good with most being moderate to good trout streams (Ref. 1). However, the warm water type of habitat gradually becomes more prevalent in the Yellowstone River and the Clarks Fork of the Yellowstone River in their lower reaches within the basin.

Trout species most common to the upper basin are the rainbow and brown which are abundant in varying proportions in many streams. In addition, native cutthroat and Eastern brook trout are present in some creeks. Mountain whitefish are also common in the region as are mountain, longnose, and white suckers. Downstream on the Yellowstone River brown trout become increasingly abundant in response to the warmer waters of the river with this species becoming dominant relative to the rainbow below Greycliff. However, neither of these salmonid fishes nor the mountain whitefish are abundant below Laurel. Below Billings the shorthead redhorse and river carp suckers tend to replace the three sucker species that are typical of the colder waters of the upper basin. In turn, goldeye, channel catfish, and sauger (all warm water species) become common in the mainstem near Billings. Gill net data obtained by the Montana Department of Fish and Game between April 1970 and August 1972 (Ref. 2) revealed that nearly one-half of the fish captured in a one-hundred mile reach of the Yellowstone River below Laurel were goldeyes with channel catfish and sauger representing about 9%. In contrast, brown trout comprised only about 1.5% of the total catch with rainbow and mountain whitefish each less than 0.5%. Various rough fish such as several sucker species, chubs, and carp made up about 39% with black bullheads and burbot (ling) comprising another 3% of the total netted.

Cutthroat trout is the native species of salmonids in much of the Upper Yellowstone Basin. In recent years, efforts have been made to preserve the cutthroat populations in various streams of the region such as Tom Miner and Big Creeks in Gallatin and Park Counties. Brook trout are also common in some of these streams. This more competitive and introduced species tends to exclude the native trout population that is endemic to the area. In addition, the introduced brown trout tends to restrict the range of rainbow, especially in warmer waters.

In addition to creeks and rivers, a variety of lakes in the Upper Yellowstone Basin support fish populations. Lentic waters at the lower altitudes, e.g., Cooney Reservoir and East Rosebud Lake, typically have a high proportion of rough fish, commonly greater than 80% of the gill net catches (Ref. 2). In contrast, high altitude lakes such as Hellroaring, Timberline, Sylvan, and Cimmerian Lakes often provide good trout fisheries of considerable variety. A survey of 75 such lakes (Ref. 2) revealed that 49% of them contained populations of trout; of the barren lakes, 43% were found to have the potential as future fisheries after stocking. Eastern brook trout, cutthroat, rainbow, and golden trout plus the arctic grayling were found in the lakes;

however, no brown trout were netted from these colder waters. Of the non-barren lakes, 65%, 49%, 22%, 14%, and 5% had populations of brook, cutthroat, rainbow, and golden trout and the grayling, respectively. Sixty-two percent of the lakes had single species; Eastern brook trout was found in 38% of them, cutthroat in 19%, and golden and rainbow trout each in 3%. Of these lakes, 19% had Eastern brook and cutthroat trout. Three species were gill netted in 16% of the lakes--brook-rainbow-grayling in 5% and rainbow-cutthroat-golden trout in 11%. Rainbow trout were found in accompaniment with other species in 88% of the cases in contrast to the brook trout which was found with another species in 42% of the cases.

Attempts to develop similar and stable trout fisheries in the low altitude lakes have generally failed. As one example, after the rotenone poisoning of Cooney Reservoir followed by a rainbow trout restocking in the following year, the high, initial recaptures of rainbow gradually declined to a re-establishment of predominately rough fish populations (Ref. 2). Cutthroat stocking in East Rosebud Lake also failed to result in any major cutthroat recaptures in the following years (Ref. 2). Such failures would be suggestive of warmer waters of a lower quality (e.g., with sediment problems) in the lowland lakes such as Cooney Reservoir resulting in less favorable biological conditions.

Most of the Yellowstone River and its tributaries above the confluence of the Clarks Fork serve as spawning grounds for various trout species. Trout spawning in the Clarks Fork drainage and in the Yellowstone mainstem below its confluence is limited due to the high silt loads of the Clarks Fork system (Ref. 1). Large quantities of suspended sediment alter the composition and abundance of aquatic organisms in a stream with a major influence being the reduction or disappearance of trout and other sport fish (Ref. 3). One effect of silt is the reduction in survival of developing trout embryos. Large concentrations of intragravel dissolved oxygen are required for salmonid embryo development (Ref. 4). Extensive silt deposition on trout redds clogs pore spaces between gravels and diminishes the oxygenation and waste removal processes to and from the eggs (Ref. 5). Suspended sediment also tends to increase water temperatures which may cause a stream to become unsuitable for the steno-oligothermal salmonids. In general, high silt loads in many streams of the Yellowstone River Basin in Montana possibly represent the major biological problem of the region. In the Upper Yellowstone Basin, this is most distinctive in the Clarks Fork drainage. The upper reaches of the Clarks Fork provide good waters for trout; however,with progressive silt accrual downstream, the lower reaches below Belfry-Bridger become poor habitat with brown and rainbow trout rare (Ref. 1). Similar problems on the Shields River have been largely rectified in recent years; as a result, in contrast to the Clarks Fork, this stream provides suitable habitat throughout its length for brown and rainbow trout, for some brook and cutthroat trout, and for the mountain whitefish (Ref. 1).

Saline seep problems which are gradually becoming factors of major impact in the Upper Yellowstone River Basin will undoubtedly have a major influence upon the aquatic biota of streams and ponds. Saline seeps are evident in most of the counties within the basin especially Carbon and Stillwater (Ref. 13, 14).

Oil field discharges are a problem in some localities of the upper basin. Differences in bottom organisms and fish above and below such effluents have been noted (Ref. 1). Some discharge occurs from the Elk Basin oil field into Silvertip Creek and the Clarks Fork Yellowstone River; however, this situation has been improved in recent years (Ref. 1). The dumping of oil wastes by refineries in the Billings-Laurel area and subsequent seepage for many years has polluted the groundwater. At certain water table levels, oil discharges into the Yellowstone River. Extensive oil inputs of this nature result in an extreme degradation of fish habitat.

Another factor that currently influences lotic biota and fisheries within some streams in the basin is their dewatering for irrigation. A specific example is Rock Creek (Clarks Fork of the Yellowstone drainage). Dewatering results in a reduction of this stream as a valuable fishery even though the creek has a good quality of water (Ref. 1). Dewatering can greatly affect the biological conditions of a stream through the physical loss of habitat, through temperature and chemical changes, and through an alteration of flow regimes that trigger various biological responses (Ref. 19).

In the Daisy Pass area at the headwaters of the Stillwater River, bottom fauna is severely reduced by the precipitation of iron and other metals due to acid mine drainage. Fish populations are also depressed. However, the Stillwater River recovers in about 1.5 to 6.5 miles downstream from this discharge.

The Stillwater and Boulder River drainages and the extreme upper reaches of the Yellowstone River and tributaries are practically devoid of major agricultural and point source pollution problems. With a few exceptions, waters in the streams are generally soft, cold, clean, and clear with low concentrations of dissolved materials and metals. Department of Fish and Game studies in the region (Ref. 15) have concluded that, in general, ". . . human activities have probably modified water quality very little." As a result, biological conditions in these streams are generally quite good.

The insect orders Plecoptera, Tricoptera, and Ephemeroptera, which are considered to be comprised of forms sensitive to pollution, made up 50% to 90% of the benthic organisms collected from the Stillwater and Boulder River drainages; numbers collected per square foot of stream bottom ranged from 60 to 2,430 (Ref. 16). These values are not any more variable than what is characteristic of non-polluted, bottom fauna communities. In addition, a variety of fish have been captured from the streams of the area--rainbow, brown, Eastern brook, and cutthroat trout, plus the mountain whitefish and longnose sucker and dace, and unidentified cyprinids (carp) (Ref. 16); these species are characteristic of cold and clear waters. Trout egg survival in the streams was found to be relatively good, ranging from 45% to 83% (Ref. 15). Growth rates of these fish were found to be slightly less than the state averages reported by Brown (1971) but are commensurate with the colder waters and shorter growing seasons that are found in these drainage systems

(Ref. 15). In turn, standing crops of trout (pounds per acre of stream) were observed as somewhat lower in this region than those reported for streams in southwestern Montana (Ref. 15 and 18). However, relative to an average tabulated for trout streams in North America, standing crops in the Stillwater and Boulder drainages can be graded as ranging from moderately low to high (Ref. 15). Fish biomass was found to be generally higher in the small and brushy, meandering tributaries than in the larger streams (Ref. 16). All of these factors are in accord with the descriptions of these streams as being good trout fisheries.

A few isolated biological problems have been observed for this particular region (Ref. 15 and 16), but these are of a different nature than those described for the rest of the Upper Yellowstone Basin. In a few small tributary streams, fish could not be netted; however, these streams are probably intermittent and have very steep grades which afford only a marginal fish habitat. In Verdigris Creek, the absence of fish can be related to its high concentration of metals. The stream passes through a gossan formation and also receives inputs from a spring distinct in its metals content. As a result, this is largely a natural phenomenon, but it has been accentuated by road building through the formation. In parts of the Stillwater River, some modifications of the stream by adjacent landowners have occurred; this has resulted in alterations of the gravel streambed which could disrupt spawning activities. In addition, a few small streams in the area are filled with mine tailings, wind-carried from a nearby tailings pond. Although the water chemistry of the streams has not been affected by these tailings, natural stream bottoms have been destroyed in 0.5 to 1 mile reaches of the creeks.

Municipal and industrial discharges also affect some of the streams in the Upper Yellowstone Basin. This is most distinct in the Laurel-Billings reach of the Yellowstone River. The Yellowstone River Pollution Study (1955) included evaluations of bottom flora and fauna throughout the Yellowstone River Basin (Ref. 7). A subsequent study in 1960 (Ref. 8) of bottom organisms indicated favorable biological conditions in the Yellowstone River from Hysham to Miles City (Middle Yellowstone River Basin) with generally unfavorable conditions between Billings and Hysham. Through 1963 the Yellowstone River biota was still being affected to Pompey's Pillar by pollution input from the Billings area (Ref. 9).

Through several field surveys a depression in the number of benthic organisms collected per square foot of river bottom has been observed from 110 to 50 individuals in the Billings area (Ref. 10). Algae below wastewater inputs in the area appeared reddish-brown in color in contrast to the good growth of distinctively green algae observed upstream (Ref. 1). The percentage of pollution sensitive organisms--Plecoptera (stoneflies), Tricoptera (caddis flies), Ephemeroptera (mayflies), and Odonata (dragon and damsel flies)--was found to decline in relation to the more tolerant groups such as the dipterans (true fly larvae), physid (air-breathing) snails, tubificids (blood worms, annelids), and <u>Sphaerotilus</u> ("sewage fungus," a bacteria), from 74% to 85% above the effluents to 0% to 31% within the receiving reach (Ref. 10). Similar results were obtained in earlier surveys; as an extreme case, no benthic organisms were collected in one survey immediately below the sewage treatment plant, Yegen Drain, and the oil refinery outfall (Ref. 12). These surveys have also indicated that the Yellowstone River is somewhat recovered from the effects of the various wastewater inputs by the time it reaches the vicinity of Huntley below Billings; benthic counts increased in this section to about 90 individuals per square foot with 87% of these representative of pollution sensitive groups (Ref. 11 and 12). However, goldeye fish with an objectionable taste were caught, not only near the refinery outfall at Billings, but also as far downstream as Pompey's Pillar below Huntley (Ref. 12). Recent control of pollution sources in the Billings-Laurel area should improve the ecological condition of the river. Improvements in the Billings-Laurel area through the last 15 to 20 years are qualitatively suggested (Ref. 1) but not definitely documented as yet.

X. MANAGEMENT STRATEGY AND PLAN

The objective of water quality management is to maintain or enhance the quality of waters within the basin. To accomplish this, management programs and plans must be developed and implemented within the basin. After development and implementation, waters and wastewaters in the basin must be checked to determine actual effectiveness of the management program. Water quality management is an interative process; that is, a plan must be followed, the results checked, the plan modified, and the results again checked. A management strategy contains a number of elements. These are:

1. Permits.

   State and federal pollutant discharge permits are a basic tool in regulating the discharge of effluents to state waters. All discharges under the permit authority either are or will be permitted or eliminated. The permit program regulates the quantity and quality of discharges of municipal and industrial wastes and certain agricultural wastes, including discharges from confined feeding operations and certain irrigation drainage systems. The discharge permit also is used to regulate effluent from new or expanded discharges. As stream quality data are obtained, the permit can be used to ensure that discharging effluents do not cause streams to exceed state water quality standards. All dischargers will be required, under the permit program, to achieve best practicable control technology not later than July 1, 1977. All publicly owned treatment works must achieve secondary treatment, and any more stringent limitation necessary to meet water quality standards, by July 1, 1977.

2. Intensive Surveys.

   Intensive water quality surveys are conducted for waters in the basin that have water quality problems. Objectives of intensive surveys are to determine pollution causes and potential means of elimination or abatement of pollutants. As additional water quality problems are identified within the basin, intensive surveys will be made. Intensive surveys also are conducted to determine the impact of specific wastewater discharges, land practices, or water treatment facilities that are installed in the basin.

3. Monitoring.

   Monitoring includes a number of activities that provide measurement of chemical, physical, and biological quality of water and changes in quality. Monitoring includes:

   (a) self-monitoring required by dischargers that are under the Pollutant Discharge Elimination System permit program;

(b) compliance monitoring by the Water Quality Bureau and the EPA to ensure that permitted discharges are in compliance with allowable limits;

(c) periodic sampling and anlysis of water at selected stations;

(d) aerial and ground observations of basin waters and practices or facilities that affect water quality;

(e) the use of continuous water quality recording instrumentation to obtain a continuous record of selected water quality parameters;

(f) short-duration surveys of stream segments to determine changes in quality in streams as the water progresses downstream;

(g) evaluation of water quality data to determine trends and to identify problems.

The basic objective of the monitoring effort is to determine the status of water quality and to determine variations in water quality. The monitoring network also is useful for determining the impact of activities within the basin that influence water quality. Such as logging, mining, and certain agricultural practices; and those activities that may enhance water quality, such as installation of improved treatment facilities.

4. Facilities Construction, Operation, and Maintenance

Federal and state grant problems are available to assist municipalities in the construction of sewage treatment facilities, which include outfall and interceptor sewers. Such facilities provide improved treatment of wastewaters and reduce the impact of wastewasters on the receiving water body. An integral part of the waste treatment facility program is adequate operation and maintenance of the facilities after construction is completed. The state requires that all operators be certified and the state provides on-the-job training and annual schools for operators.

5. Operation and Maintenance

Periodic inspections are made of municipal and industrial wastewater treatment facilities in the basin. The objective of operation and maintenance inspections is to ensure that waste treatment facilities are operated in a manner that provides the best possible treatment.

6. Information and Education

Information is made available to the public through bureau publications, talks, technology transfer seminars, and through answering inquiries. Public hearings and environmental impact statements are presented for important or controversial issues in the basin. Information and educational efforts are informing the public of water quality conditions in the basin and factors that can degrade water quality. This effort stresses development of a pollution prevention attitude.

7. Regulations and Guidelines

To prevent water quality degradation within the basin, regulations and guidelines that relate to water quality will be made available to residents of the basin through state and county organizations. This includes regulations that influence water and wastewater facilities. In addition, existing regulations may be changed or updated to control activities within the basin that will degrade water quality. The Department of Health and Environmental Sciences, in cooperation with other agencies, will develop guidelines that will abate or eliminate pollution resulting from storm drainage, storm sewer discharges and non-point sources, including irrigation practices, road building, construction, logging practices, overgrazing and other practices. Land use is recognized as a dominant factor controling water quality in the basin. Those activities which influence land use will be examined to determine how water quality degradation due to improper land uses can be eliminated or be abated.

8. Enforcement

Violations of Montana's laws, rules, or permits are investigated and are subject to injunction, civil penalties, or criminal penalties. The rules and regulations upon which enforcement is based are periodically reviewed and updated to ensure that Montana's laws and regulations are adequate and can be properly enforced.

9. Program Coordination

Montana's water pollution control program will be coordinated with other state, federal, and local agencies to ensure that the activities of these groups receive adequate information with respect to their water quality related activities. This includes review of proposed programs, laws, regulations, and proposed technical investigations that relate to water quality.

The elements of basin water quality management described above generally are applicable to all basins. Specific steps that will be taken in the Upper Yellowstone basin are:

1. Permits.

Permit conditions and progress in meeting compliance schedules will be reviewed for all dischargers in the basin in FY 1976. All permits will be reviewed prior to expiration to determine what revisions are needed for the reissued permits. All dischargers that have not received permits, but are under the NPDES or MPDES, will receive permits in FY 1976.

2. Intensive Surveys

In FY 1976, intensive surveys are planned for the Yellowstone River and the municipal, industrial, and non-point source discharges in the Billings-Laurel area. As additional water quality problems are identified and as funding is available, additional intensive surveys will be conducted. Many non-point source problems will be investigated through intensive surveys. The investigation of non-point sources is contingent upon funding.

3. Monitoring

See Section XI (Monitoring and Surveillance) for specific basic strategy and plans.

4. Facilities Construction, Operation, and Maintenance

Inadequate municipal sewage treatment has been ranked according to priority (Table 3) and will be upgraded to meet secondary treatment by July 1977. Industrial treatment of wastewater discharges will meet best practicable treatment by July 1977. Some EPA and state grant funds will be available for municipal sewage facilities. Sewage treatment plant operator training and the operators school will be available for the basin.

5. Operation and Maintenance

At least one inspection will be made annually of each municipal sewage treatment facility in the Upper Yellowstone River basin. Critical installations will be provided additional inspections when needed and facilities with special operation and maintenance problems will be provided with technical assistance.

Major industrial dischargers are examined at least twice per year and minor dischargers are examined as needed and as manpower and funding are available.

6. Information and Education

The general bureau information and education program will be utilized in the basin. No specific basin programs are planned for the next year.

7. Regulations and Guidelines

During the next year the regulatory framework for water pollution control will be reviewed by the bureau attorney. The adequacy of the regulations to prevent pollution will be assessed.

8. Enforcement

Enforcement actions will be taken as needed for prosecution of violations of the state's water pollution laws and regulations.

9. Program Coordination

Federal, state, and private organizations that have water quality related actions in the basin will be informed of the Bureau's efforts and will be requested to furnish information on these basin programs.

10. Waste Load Allocations

Several water quality limited stream segments occur in the Upper Yellowstone River Basin; examples are the Gardiner River, the Clarks Fork Yellowstone River, and possibly the upper Stillwater River. These streams will not be allocated however, due to the non-point nature of the pollution. The Yellowstone River in the vicinity of Billings is also a water quality limited segment but due in part to point source inputs of wastewater. As a result, a wasteload allocation investigation is currently underway on this segment although not yet completed as of this writing. Dissolved oxygen and BOD apparently do not pose a problem to the stream and will therefore not be allocated. Fecal coliforms, temperature, and possibly phenols however will be allocated for the segment. The effect of these allocations on second generation permits is not known at the present time. Preliminary results indicate that thermal discharges will be held at least to present levels; at a minimum, the same will hold true for the remaining allocatable parameters.

11. Non-Point Strategy

The program developed by the Mid-Yellowstone Areawide Planning Organization will be utilized to identify non-point source problems and to recommend corrections (for example, in the Clarks Fork River). The organization now in existence covers a large percentage of the Upper Yellowstone Basin including Yellowstone, Carbon, Stillwater, and Sweet Grass Counties. The inclusion of Park County, which is currently showing an interest in joining this particular group, would complete the area of the basin. Thus the Statewide 208 would not be directly involved in this basin unless Park County decided to remain autonomous.

XI. MONITORING AND SURVEILLANCE

Water quality monitoring and surveillance programs represent a major investment of time and funds. Such programs should obtain the needed information at least cost. To properly design a cost-effective monitoring system, a number of factors must be considered including:

1. Adequacy of baseline data in the basin;
2. Status of the stream as a receiving water for pollutant discharges;
3. Data needs for point source discharges under state and federal permit programs;
4. Existing and potential water quality problems;
5. Data needs for enforcement actions;
6. Available time and funding;
7. Existence of other water quality data collection programs in the area.

Flexibility in scope and intensity is an important aspect of a proposed program. A variety of factors can influence an area's water quality; these include industrial, municipal, and agricultural developments, federal and state regulations, and water transfers. With the range of developments that can occur in a basin, a long-term management strategy cannot be efficiently developed. Water quality surveillance and monitoring is directed at short-term conditions (up to five years in the future) and is revised annually.

Monitoring and surveillance recommendations are presented in this report. The detailed basin monitoring and surveillance program is developed by the Water Quality Bureau as part of the annual water pollution control program plan. Monitoring and surveillance activities are conducted by a variety of organizations including communities and industries, federal and state agencies, private individuals and organizations. Commonly, acute problems such as toxic conditions causing fish kills, oil spills, etc., are recognized by basin residents or persons working in the basin.

The following is the recommended monitoring program for the Upper Yellowstone River basin.

1. Compliance Monitoring

   The following point discharges should be monitored to check compliance with discharge permit conditons.

Billings (WWTP & WTP)	Roberts
Laurel (WWTP & WTP)	Joliet
Edgar	Park City
Fromberg	Columbus

Bridger	Absarokee
Belfry	Yellowstone Boys Ranch
Bearcreek	Big Timber
Gardiner (WWTP & WTP)	Livingston (WWTP & WTP)

Suspended solids, BOD_5, fecal coliforms, and flow should be monitored in all municipal discharges; residual chlorine should be measured where chlorination is provided. Municipal water treatment plant discharges should be monitored for aluminum, suspended residue, turbidity, flow, pH, and residual chlorine.

Similarly, the following industrial discharges should be monitored to check compliance with permit conditions:

Burlington Northern, Laurel and Livingston
Cenex Oil Refinery, Laurel
Montana Power Company, Billings
Great Western Sugar Company, Billings
Continental Oil Refinery, Billings
Exxon Oil Refinery, Billings
Montana Sulfur and Chemical Company, Billings
Empire Sand and Gravel Company, Billings

Frequency and parameters to be monitored for irrigation return flows have not, as yet, been defined. Feedlots are designed basically as non-discharging facilities. It is recommended that the discharge from Blue Water Fish Hatchery, Fromberg, be monitored by the Water Quality Bureau to check compliance with permit conditons.

2. Self-Monitoring

All waste dischargers under MPDES permit are required to periodically sample and analyze their wastewater and report the results to the Bureau and the Environmental Protection Agency. The parameters to be monitored are specified in the conditions of the permit.

3. Water Quality Surveillance Network

The water quality surveillance network is composed of water quality sampling stations on streams, waterbodies and groundwater. Surveillance is recommended for the following streams:

Stream	Site	Reason
Yellowstone River	at Billings	Municipal & Industrial
Canyon Creek	near Billings	Sediment
Clarks Fork River	near Belfry	Sediment
Silver Tip Creek	near Belfry	Sediment, Oil
Red Lodge Creek	above Cooney Reservoir	Sediment, Nutrients
Red Lodge Creek	below Cooney Reservoir	Nutrients, Sediment
Rock Creek	near Red Lodge	Municipal, Sediment

Stream	Site	Reason
Rock Creek	near Rockvale	Sediment, Dewatering
Clarks Fork River	near Laurel	Sediment, Nutrients
Rosebud Creek	near Absarokee	Municipal, Sediment, Nutrients
West Fork Still-water River	near Nye	Sediment, Metals
Stillwater River	near Beehive	Sediment, Metals
Stillwater River	near Columbus	Sediment, Metals
West Boulder River	near McLeod	Sediment, Metals
East Boulder River	near mouth	Sediment, Metals
Boulder River	near Contact	Sediment, Metals
Boulder River	near Big Timber	Sediment, Metals
Shields River	near Livingston	Sediment
Yellowstone River	near Livingston	Municipal, Industrial

Recommended surveillance frequency varies from continuously to quarterly and parameters to be monitored generally include flow, sediment, temperature, nutrients, common ions, metals, and coliform organisms.

The actual basin surveillance program is described in the bureau annual water pollution control program plan. Details of sampling frequency and parameters also are described in this plan.

Biological assessment and water quality runs will be carried out at selected sites in the basin. Biological assessments involve periodic quantitative and/or qualitative benthic organism assessments. Water quality runs involve an intense instream survey of a few water quality parameters at a large number of stations. The sampling is designed to measure changes in stream quality as the water moves downstream. Sites selected for these evaluations are described in the Bureau's annual pollution control plan.

4. Aerial and Ground Surveys

Examination of streams and water bodies is done as part of the routine bureau visits to the basin. Other agencies and organizations also commonly notice stream conditions during their basin trips. Detailed aerial surveillance and actual stream examination on foot or by boat is required for selected problems. For example, the Yellowstone River in the Billings-Laurel area should be examined in detail by boating the stream annually.

5. Data Interpretation and Analysis

Surveillance and monitoring activities develop water quality data that must be compared with previous data, water quality standards, permit conditions, etc. Results of water quality testing must be analyzed and interpreted to understand temporal and spatial changes in water quality and determine if the sampling network is adequate to meet program objectives.

XII. WASTE LOAD ALLOCATION

The Gardiner River is classified as a water quality limited segment because of the constituents draining into the river from natural hot springs in Yellowstone National Park. High arsenic values are of particular concern. There are no point source effluents in the drainage, so no waste load allocation has been made.

The Upper Stillwater River drainage to Beehive is a water quality limited segment. This is due to the high metals and acidity. This condition exists because of past mining activities in the Upper Stillwater drainage. These conditions are non-point in nature and thus no waste load allocation has been made.

The Clarks Fork of the Yellowstone River is also classified as a water quality limited segment because of high turbidity and sediment values. These problems are due to the fragile soils in the Clarks Fork of the Yellowstone River drainage, the poor land conservation practices, and the continual overgrazing of lands in the drainage. These problems are non-point in nature. No waste load allocation has been made.

The Yellowstone River from Laurel to Billings has been classified water quality limited. This is largely due to high coliform counts in this reach of the river. This condition seems to be caused from the Laurel and Billings wastewater treatment plant effluents, city storm drains in both Laurel and Billings, the Great Western Sugar Company lagoon discharge, and a number of confined feeding operations. The Clarks Fork of the Yellowstone River empties into the Yellowstone in this segment and thus causes a sediment problem. Also, Canyon Creek, a tributary of the Yellowstone in this reach, seems to carry a significant amount of sediment laden irrigation return water to the Yellowstone River.

Before waste load allocations can be made for the Yellowstone River from Laurel to Billings, additional information is needed. A study entitled "Waste Load Allocation Investigation of the Yellowstone River in the Vicinity of Billings, Montana" has been initiated by the Water Quality Bureau through a grant from EPA. The study has a duration of one year. The objectives of the study are to prepare a waste load allocation for the various point source discharges and to determine the impact from any non-point sources. The waste load allocations will take into account existing effluents, proposed changes in existing effluents and the possibility of new future effluents to the river.

This waste load allocation study has not been completed at the present time. Preliminary conclusions have been briefly described in the "Management Strategy and Plan" section of this report. Biological and chemical data collected in the study indicate that the Yellowstone River between Laurel and Huntley has been greatly improved from past years due to the updating and improvement of wastewater treatment facilities in the area.

There are no other designated water quality limited segments in the Upper Yellowstone River Basin. There are several streams which do not meet the State's current classification (e.g., Silvertip Creek) due to sediment problems arising from natural sources. More funding is needed to identify all such streams in the basin.

XIII. WATER QUALITY PROBLEMS AND FUTURE NEEDS

A variety of point and non-point water pollution problems have been identified in this report and are summarized in Tables 18 and 19. The problems originate from a variety of sources and have a variation in severity and potential for correction. This water quality management plan has generally identified the location and type of problems, and background details concerning these problems are presented in the report. Considerable additional work is needed to further define these problems, determine techniques for abatement or elimination, and implement actions to correct the problems.

Three basic elements are needed in the basin to successfully improve water quality and prevent further quality degradation. These are (1) a program of education and information to relate these problems to the public, an (2) increased funding for further technical identification of problems and potential solutions and (3) funding to implement corrective measures and to determine if corrections are successful in improving water quality.

Table 18

SUMMARY OF WATER POLLUTION PROBLEMS IN THE UPPER YELLOWSTONE RIVER BASIN

Problem	Stream or Area	Status	Potential for Correction	Methods of Correction
Municipal wastewater discharges that degrade stream quality. Low to moderately severe problem.	Primarily Yellowstone River but includes other streams.	Problem decreasing. All treatment facility on MPDES permit. Communities are upgrading treatment process.	Good. Additional grant funding needed.	Construction of secondary treatment facilities.
Industrial discharges that degrade stream quality. Moderately severe problem.	Primarily Yellowstone River, also other streams.	Problem decreasing or stable. All discharges on MPDES permit. Waste treatment at industrial facilities being upgraded.	Good. Additional effort needed to meet treatment requirements.	Construction of improved treatment facilities.
Saline seep. Loss of productive land to saline groundwater. Increased stream salinity a major problem.	Yellowstone and Clarks Fork Yellowstone Rivers and Canyon Creek.	Increasing. Some study effort but little corrective effort to date.	Poor to fair. An economically difficult problem. Technical corrective measures not well known.	Cropping practice changes. Land use changes. Much additional investigation of causes and potential solutions needed.
Stream pollution & habitat degradation due to confined livestock feeding & wintering operations. Problem severity low to moderate.	Many streams in basin.	Increasing. Problem not well defined. MPDES permits required on larger feedlots. Additional evaluation needed.	Good. Corrective techniques readily available. Education and information problem. Additional surveys needed to pinpoint problem areas.	Stream bank fencing. Construction of runoff holding ponds. Relocation of feedlots and livestock wintering operations.

Table 18
(Continued)

Problem	Stream or Area	Stream	Potential for Correction	Methods of Correction
Irrigation return flows. Stream degradation due to run-off from agricultural lands that cause increased temperature, salinity, nutrients, pesticides and suspended sediment. Moderate to severe problem.	Primarily Yellowstone and Clarks Fork Yellowstone Rivers, Canyon Creek, and Rock Creek.	Rapidly expanding irrigation is leading to more return flows. Problems need much additional investigation to determine impact.	Fair to good. Manipulation of irrigation practice involves education, informational and technical study.	Better water management. Better use of return flows. Identification of problem areas and change water use in these areas.
Urban runoff causing water quality degradation in streams. Moderately severe problem.	Primarily Yellowstone River, also other streams.	Increasing slowly by increased population. Not well understood. Primarily from larger communities.	Good. Technical methods available. Requires additional funding for treatment facilities. Treatment sites difficult to obtain.	Use of treatment ponds. Good drainage control.
Stream dewatering causing increased temperature & loss of aquatic habitat. Moderate to severe problem.	Yellowstone & Clarks Fork Yellowstone Rivers, Rock Creek, & other streams.	Rapidly increasing due to irrigation and industrial diversions. Impact on streams needs much more investigation.	Fair to poor. Economics of use of diverted water conflicts with in-stream aquatic needs.	Better water management & water storage Denial of water diversions during critical flow periods.
Acid mine drainage causes low pH values & higher metals concentrations. Moderate to severe problem.	Upper Stillwater River drainage.	Problem stable. Some study effort but little corrective effort to date.	Fair to good. Requires additional funding for detailed study and corrective measures.	Good drainage control. Use of treatment ponds where possible.

Table 18
(Continued)

Problem	Stream or Area	Stream	Potential for Correction	Methods of Correction
Oil seepage. Causes phenolic tastes in water and fish. Problem is moderate.	Yellowstone River in Laurel and Billings areas.	Problem stable. Some study & corrective effort to date.	Fair to good. Requires additional concern by responsible parties.	Collection and treatment such as skimming facilities.

Table 19

Degraded streams in the Upper Yellowstone River Basin summarized by cause and the estimated miles of streams so degraded for the entire Yellowstone region; asterisks illustrate plausible levels of impact (***--relatively severe to *--slight) while the question marks indicate some degree of uncertainty in such predictions.

Stream Segment	SEDIMENT	TEMPERATURE	DEWATERING	SALTS	NUTRIENTS	COLIFORMS	ACID MINE WATER AND TOXIC METALS	OIL AND GREASE, PHENOLS	AS, F FROM YELLOWSTONE PARK
Gardiner River									***
Yellowstone River above Livingston									**
Yellowstone tributaries above Livingston						*?			
Yellowstone River near Livingston								*	**?
Shields River	**?					*			
Yellowstone R. between Livingston and Big Timber						?			*
East Boulder River	*?						*?		
Boulder River near mouth	?					*?	?		
Rosebud River						*?	?		
Yellowstone R. between Big Timber and Columbus						*?			*
Upper Stillwater River (headwaters)	?						***		
Yellowstone R. between Columbus and Laurel	?					*?			*?
Yellowstone tributaries below Big Timber				0 to ***					
Clarks Fork of Yellowstone River	***	*?		*	*	*		*?	
West Fork Rock Creek						*?			
Rock Creek	*?	?	***?		?	*			
Rock Cr. tributaries	*				*				
Silvertip Creek	***	*?		***	*?			*	
Bear Creek						*			
Clarks Fork River tributaries	***	*?		***	*?				

Table 19

(Continued)

Stream Segment	SEDIMENT	TEMPERATURE	DEWATERING	SALTS	NUTRIENTS	COLIFORMS	ACID MINE WATER AND TOXIC METALS	OIL AND GREASE, PHENOLS	AS, F FROM YELLOWSTONE PARK
Yellowstone River below Laurel	*	*?		*?	*?	**		**	*?
Canyon Creek	***			*					
Upper Yellowstone Basin	80	?	?	?	?	25a	?	25a	61
Middle Yellowstone Basin	150a			86a					
Lower Yellowstone Basin	?								

(a) Indicates overlap of degradation causes.
Mileage information from the "Montana Water Pollution Control Program Plan for Fiscal Yeat 1976" prepared by the Water Quality Bureau, Montana Department of Health and Environmental Sciences (Ref. 2).

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REFERENCES

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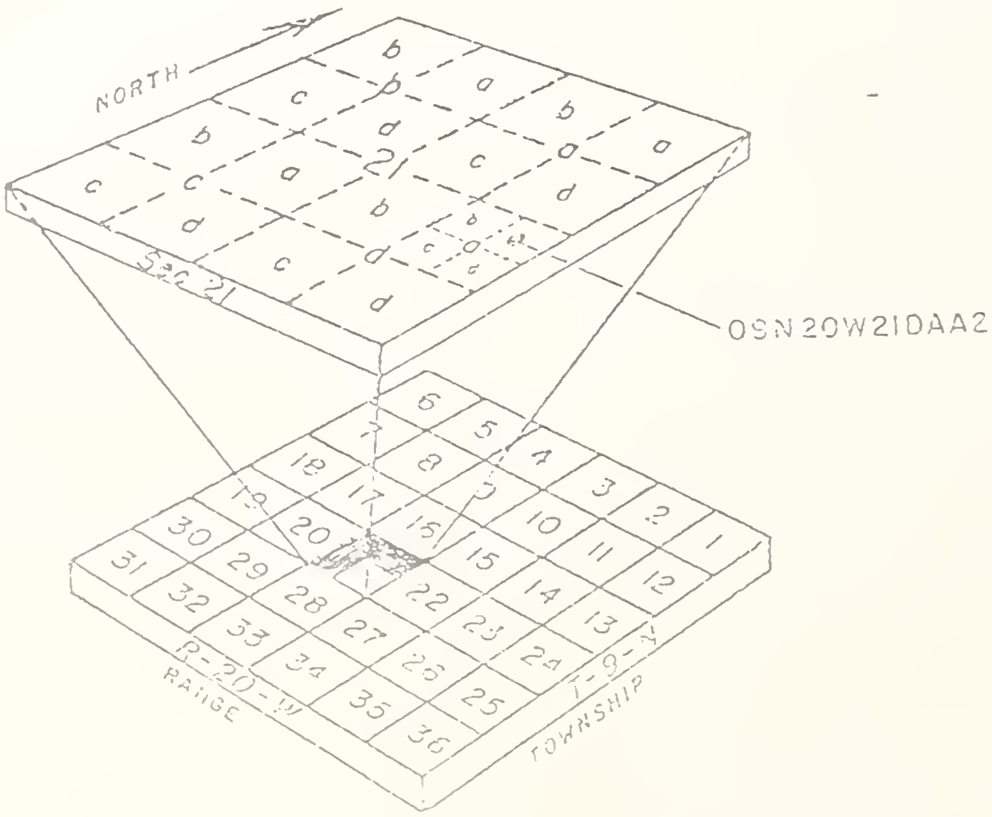
A P P E N D I X

APPENDIX A

SYSTEM FOR GEOGRAPHIC LOCATION OF FEATURES

Wells, springs, water-sampling locations, and stream-gaging locations are assigned numbers based on the system of land subdivision used by the U. S. Bureau of Land Management. The number consists of twelve characters and describes the location by township, range, section, and position within the section. The figure below illustrates the numbering method. The first three characters of the number give the township, the next three characters the range. The next two numbers give the section number within the township, and the next three letters describe the location within the quarter section (160-acre tract) and the quarter-quarter section (40-acre tract), and the quarter-quarter-quarter section (10-acre tract). These subdivisions of the 640-acre section are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quadrant. If there is more than one feature in a 10-acre tract, consecutive digits beginning with 2 are added to the number. For example, if a water-quality sample was collected in sec.21,T.9N.,R20W, it would be numbered 09N20W21DAA2. The letters DAA indicate that the well is in the NE¼ of the NE¼ of the SE¼, and the number 2 following the letters DAA indicates there is more than one water-quality sampling location in this 10-acre tract.



MONTANA STATE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

MAC 16-2.14(10)-S14480 WATER QUALITY STANDARDS

(1) Policy statement. The following standards are adopted to establish maximum allowable changes in water quality and establish limits for pollutants which affect prescribed beneficial uses of state waters. The department adopts as a rule the policy that best practicable treatment and control of waste, activity and flow is to be provided to maintain dissolved oxygen and overall water quality at the highest possible levels, and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor and other deleterious substances at the lowest possible levels.

(2) Application of standards. The water quality standards are composed of water-use classifications [section (4)], water-use descriptions and specific water quality criteria [section (5)], and general water quality criteria [section (6)].

(a) General water quality criteria apply to all state waters except where in this rule specific water quality criteria are more applicable to a specific water-use classification.

(b) In order to carry out the objective of the rule, existing discharges to state waters shall be brought into compliance with the standards as soon as practicable, and in no case later than three years from the effective date of the rule.

(3) Definitions. Unless statutory definition or the context otherwise requires in this rule:

"Conduit" means any artificial or natural duct, either open or closed, for conveying liquids or other fluids.

"Dewatered stream" means a perennial or intermittent stream whose water has been removed for one or more beneficial uses.

"EPA" means the U. S. Environmental Protection Agency.

"Intermittent stream" means a stream or portion of a stream that flows only in direct response to precipitation; it receives little or no water from springs and no long-continued supply from melting snow or other sources.

"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil and water conservation practices have been applied. Conditions resulting from dams in existence as of July 1, 1971 are natural.

"Mixing zone" means that volume of state water wherein any pollutant may exceed allowable water quality standards.

"Pesticide" means insecticides, herbicides, rodenticides, fungicides or any substance or mixture of substances intended for preventing, destroying, controlling, repelling, altering life processes, or mitigating any insects, rodents, nematodes, fungi, weeds and other forms of plant or animal life.

"Residue" means oils, floating solids and sludge deposits.

"Sediment" means solid material settled from suspension in a liquid; mineral or organic solid material that is being transported or has been moved from its site of origin by air, water or ice and has come to rest on the earth's surface, either above or below sea level; or inorganic or organic particles originating from weathering, chemical precipitation or biological activity.

"Settleable solids" means inorganic or organic particles that are being transported or have been transported by water from the site or sites of origin and are settled or are capable of being settled from suspension.

"Sewer" means a pipe or conduit that carries wastewater or drainage water.

"State waters" means any body of water, irrigation system or drainage system, either surface or underground. This section shall not apply to irrigation waters where the waters are used up within the irrigation system and said waters are not returned to any other state waters. The term "state waters" as used in this rule does not include underground water.

"Storm sewer" or "storm drain" means a sewer that carries storm water and surface water, street wash and other wash waters, or drainage but excludes sewage and industrial wastes.

"True color" means the color of water from which the turbidity has been removed.

"Turbidity" means a condition in water or wastewater caused by the presence of suspended matter resulting in the scattering and absorption of light rays.

(4) Water-use classifications.

Yellowstone River:

Yellowstone River drainage from the Yellowstone Park Boundary to the Laurel water supply intake B-D1

Yellowstone River drainage from the Laurel water supply intake to the Billings water supply intake except the tributaries listed below B-D2

Clarks Fork Yellowstone River drainage from source to the Wyoming state line and from the Wyoming state line to and including Jack Creek near Bridger . . . . B-D_1

Clarks Fork Yellowstone River (mainstem) from Jack Creek to the Yellowstone River . . . . B-D_2

Tributaries to the Clarks Fork Yellowstone River from Jack Creek to the Yellowstone River except the West Fork of Rock Creek listed below . . . . B-D_1

West Fork of Rock Creek drainage to the Red Lodge water supply intake . . . . A-Open-D_1

Remainder of West Fork of Rock Creek drainage . . . . . . B-D_1

(5) Water-use description and specific water quality criteria.

(c) A-Open-D_1 classification.

(i) Water-use description. Water supply for drinking, culinary and food processing purposes suitable for use after simple disinfection and removal of naturally present impurities. Water quality is to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply. Where the waters are used for swimming or other water-contact sports, analyses are to be made by the utility owner and the department to determine if a higher degree of treatment is required for potable water use.

Waters, if shown to meet the A-Closed criteria, may be so classified by the department at the request of the utility owner. State waters within the boundaries of national parks and nationally designated wild, wilderness or primitive areas in the state are classified A-Open-D_1 except those adjacent to developed areas such as Snyder Creek through the community of Lake McDonald and Swiftcurrent Creek below the Many Glacier Chalet, both in Glacier National Park. Also, Georgetown, Flathead and Whitefish lakes and Lake Mary Ronan are classified A-Open-D_1 as are some streams presently used for domestic water supply.

(ii) Specific water quality criteria.

(aa) The average number of organisms in the coliform group is not to exceed 50 per 100 milliliters where demonstrated to be the result of domestic sewage.

(ab) Dissolved oxygen concentration is not to be reduced below 7.0 milligrams per liter.

(ac) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 is to be less than 0.5 pH unit. Natural pH outside this range is to be maintained without change. Natural pH above 7.0 is to be maintained above 7.0.

(ad) No increase above naturally occurring turbidity is allowed.

(ae) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(af) No increases above naturally occurring concentrations of sediment, settleable solids or residues, which adversely affect the use indicated, are allowed.

(ag) Concentrations of toxic or other deleterious substances, pesticides and organic and inorganic materials including heavy metals, after treatment for domestic use, are not to exceed the recommended limits established in the 1962 U. S. Public Health Service Drinking Water Standards or subsequent editions; an increase of more than 10 percent of the concentration present in the receiving water is not allowed; maximum allowable concentrations are to be less than acute or chronic problem levels as revealed by bioassay or other methods.

(ah) True color is not to be increased more than two units above naturally occurring color.

(d) B-D1 classification.

(i) Water-use description. The quality is to be maintained suitable for drinking, culinary and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection and any additional treatment necessary to remove naturally present impurities; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(ii) Specific water quality criteria.

(aa) The average number of organisms in the fecal coliform group is not to exceed 200 per 100 milliliters, nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters. The average number of organisms in the coliform group is not to exceed 1,000 per 100 milliliters, nor are 20 percent of the samples to exceed 1,000 coliforms per 100 milliliters during any 30-day period.

(ab) Dissolved oxygen concentration is not to be reduced below 7.0 milligrams per liter.

(ac) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 is to be less than 0.5 pH unit. Natural pH outside this range is to be maintained without change. Natural pH above 7.0 is to be maintained above 7.0.

(ad) The maximum allowable increase above naturally occurring turbidity is 5 Jackson Candle Units except as is permitted in the general water quality criteria.

(ae) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

This applies to all waters in the state classified B-D_1 except for Prickly Pear Creek from McClellan Creek to the Montana Highway No. 433 crossing where a 2° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 65° F; within the naturally occurring range of 65° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F.

(af) No increases above naturally occurring concentrations of sediment, settleable solids or residues, which adversely affect the use indicated, are allowed.

(ag) Concentrations of toxic or other deleterious substances, pesticides and organic and inorganic materials including heavy metals, after treatment for domestic use, are not to exceed the recommended limits contained in the 1962 U. S. Public Health Service Drinking Water Standards or subsequent editions; also, maximum allowable concentrations are to be less than acute or chronic problem levels as revealed by bioassay or other methods.

(ah) True color is not to be increased more than five units above naturally occurring color.

(e) B-D_2 classification.

(i) Water-use description. The quality is to be maintained suitable for drinking, culinary and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection and any additional treatment necessary to remove naturally present impurities; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

(ii) Specific water quality criteria.

(aa) The average number of organisms in the fecal coliform group is not to exceed 200 per 100 milliliters nor are 10 percent of the total samples during any 30-day period to exceed 400 fecal coliforms per 100 milliliters. The average number of organisms in the coliform group is not to exceed 1,000 per 100 milliliters nor are 20 percent of the samples to exceed 1,000 coliforms per 100 milliliters during any 30-day period.

(ab) Dissolved oxygen concentration is not to be reduced below 7.0 milligrams per liter from October 1 through June 1 nor below 6.0 milligrams per liter from June 2 through September 30.

(ac) Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 9.0 is to be less than 0.5 pH unit. Natural pH outside this range is to be maintained without change. Natural pH above 7.0 is to be maintained above 7.0.

(ad) The maximum allowable increase above naturally occurring turbidity is 10 Jackson Candle Units, except as is permitted in the general water quality criteria.

(ae) A 1° F maximum increase above naturally occurring water temperature is allowed within the range of 32° F to 66° F; within the naturally occurring range of 66° F to 66.5° F, no discharge is allowed which will cause the water temperature to exceed 67° F; and where the naturally occurring water temperature is 66.5° F or greater, the maximum allowable increase in water temperature is 0.5° F. A 2° F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55° F, and a 2° F maximum decrease below naturally occurring water temperature is allowed within the range of 55° F to 32° F.

(af) No increases above naturally occurring concentrations of sediment, settleable solids or residues, which adversely affect the use indicated, are allowed.

(ag) Concentrations of toxic or other deleterious substances, pesticides and organic and inorganic materials including heavy metals, after treatment for domestic use, are not to exceed the recommended limits contained in the 1962 U. S. Public Health Service Drinking Water Standards or subsequent editions; also, maximum allowable concentrations are to be less than acute or chronic problem levels as revealed by bioassay or other methods.

(ah) True color is not to be increased more than five units above naturally occurring color.

(6) General water quality criteria.

(a) The degree of waste treatment required to restore and maintain the standards is to be determined by the department and is to be based on the following.

(i) The state's policy of nondegradation of existing high water quality as described in Section 69-4808.2, R.C.M. 1947.

(ii) Present and anticipated beneficial uses of the receiving water.

(iii) The quality and nature of flow of the receiving water.

(iv) The quantity and quality of the sewage, industrial waste or other waste to be treated.

(v) The presence or absence of other sources of pollution on the same watershed.

(b) Sewage is to receive a minimum of secondary treatment as defined by EPA in accordance with requirements as set forth in the Federal Water Pollution Control Act Amendments of 1972.

(c) Industrial waste is to receive, as a minimum, treatment equivalent to the best practicable control technology currently available (BPCT) as defined by EPA. In cases where BPCT is not defined by EPA, industrial waste is to receive, after maximum practicable in-plant control, a minimum of secondary treatment or equivalent.

(d) For design of disposal systems, stream flow dilution requirements are to be based on minimum consecutive seven-day average flow which may be expected to occur on the average of once in ten years. When dilution flows are less than the above design flow at a point discharge, the discharge is to be governed by the permit conditions developed for the discharge through the waste discharge permit program.

(e) State surface waters are to be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will:

(i) Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.

(ii) Create floating debris, scum, a visible oil film (or be present in concentrations at or in excess of 10 milligrams per liter) or globules of grease or other floating materials.

(iii) Produce odors, colors or other conditions as to create a nuisance or render undesirable tastes to fish flesh or make fish inedible.

(iv) Create concentrations or combinations of materials which are toxic or harmful to human, animal, plant or aquatic life.

(v) Create conditions which produce undesirable aquatic life.

(f) No wastes are to be discharged and no activities conducted such that the wastes or activities, either alone or in combination with other wastes or activities, will violate, or can reasonably be expected to violate, any of the standards; (e.g., in a reach of stream classified B-D_I, the total allowable cumulative increase to naturally occurring turbidity conditions in the reach is 5 Jackson Candle Units).

(g) No wastes are to be discharged and no activities conducted which, either alone or in combination with other wastes or activities, will cause turbidities to exceed those allowed by specific water quality criteria; provided, short-term activities necessary to accommodate essential dredging, channel or bank alterations, stream diversions or other construction where turbidities in excess of the criteria are unavoidable, may be authorized by the department under conditions as it may prescribe.

(h) Methods of sample collection, preservation and analysis used to determine compliance with the standards are to be in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association or in accordance with tests or procedures that have been found to be equally or more applicable.

(i) For operations of existing water impoundments that cause conditions harmful to prescribed beneficial uses of state waters, it is to be demonstrated to the satisfaction of the department that continued operations will be done in the best practicable manner to minimize harmful effects and will not violate state laws or department rules. New water impoundments shall be designed to provide temperature variations in discharging water that maintain or enhance the existing propagating fishery and associated aquatic life. As a guide, the following temperature variations are recommended: Continuously less than 40° F during the months of January and February, and continuously greater than 44° F during the months of June through September.

(j) Ponds for waste treatment purposes are not to be located in drainage ways where the volume of drainage water from a 10-year storm entering the ponds exceeds one-half the volume of the pond; provided that, subject to approval by the department as to design and maintenance, ponds located in drainage ways for the express purpose of containing emergency oil spills are permitted.

(k) Dumping of snow from municipal and/or parking lot snow removal activities into waters of the state is prohibited without a permit from the department.

(l) Existing discharges to state waters will be entitled a mixing zone as determined by the department.

(m) Until such time as minimum stream flows are established for dewatered streams, the minimum treatment requirements for discharges to dewatered receiving streams are to be no less than the minimum treatment requirements prescribed.

(n) Treatment requirements for discharges to intermittent streams are to be no less than the minimum treatment requirements prescribed.

(o) Pollution resulting from storm drainage, storm sewer discharges, and non-point sources, including irrigation practices, road building, construction, logging practices, overgrazing and other practices, are to be eliminated or minimized as ordered by the department.

(p) Application of pesticides in or adjacent to state waters is to be in compliance with the labeled direction, and in accordance with provisions of the Montana Pesticides Act (Title 27, Chapter 2, R.C.M. 1947) and the Federal Environmental Pesticides Control Act (Public Law 92-516). Excess pesticides and pesticide containers are not to be disposed of in a manner or in a location where they are likely to pollute state waters.

(q) The following radiological criteria shall apply to all waters except those classified as A-Closed:

(i) The average dissolved concentrations (including the naturally occurring or background contribution) of iodine 131, radium-226, strontium-89, strontium-90 and tritium are not to exceed the following concentration limits:

Iodine-131	5 pCi/L
Radium-226	1 pCi/L
Strontium-89	100 pCi/L
Strontium-90	10 pCi/L
Tritium	3,000 pCi/L

For all other radionuclides, the average dissolved concentration limits are to be 1/150 of the corresponding maximum permissible concentration in water for continuous occupational exposure as recommended by the National Committee on Radiation Protection (National Bureau of Standards Handbook 69 or subsequent revisions.)

(ii) For a mixture of radionuclides, the following relationship is to be satisfied:

$$\frac{C_1}{L_1} + \frac{C_2}{L_2} \cdots + \frac{C_n}{L_n} \leq 1.00$$

C denotes the average concentration of the respective radionuclide, and L denotes its concentration limit.

(iii) Where alpha emitters, strontium-90, radium-228, iodine-129, iodine-130 and lead-210 are known to be absent, routine analyses for dissolved gross beta radioactivity (excluding potassium-40 contribution) may be employed to monitor and show compliance with this criterion (except for tritium) as long as the gross concentration does not exceed 100 pCi/L. When these conditions are not met, routine quantitative analyses of individual radionuclides are to be performed to show compliance. Except in cases where tritium from other than natural sources is known to be absent, routine tritium analyses are to be performed to show compliance. (Note: "Absence" means a negligibly small fraction of the specific concentration limit, where the limit for unidentified alpha emitters is taken as the limit for radium-226.)

(iv) For radionuclides associated with suspended material in transport, the average concentration limits are to be 1/150 of the corresponding maximum permissible concentration in water (insoluble form) for continuous occupational exposure as recommended by the National Committee on Radiation Protection. In-stream sedimentation of these materials is not to produce solids beds that are not in compliance with subsections (q) (i) and (q) (ii) (because of leaching) and/or excessive accumulation in native flora and fauna.

(v) Average concentrations are to be computed from monitoring data acquired during the previous 12 months; maximum concentrations are not to exceed three times the average concentration limits specified.

(vi) Variances from concentration limits specified will be permitted only if the contributing source is non-controllable or a natural source. Best available treatment must be provided for man-made discharges, and the exposure received by affected population groups must be within established dose limits.

(r) No wastes are to be discharged and no activities conducted which, either alone or in combination with other wastes or activities, will result in the dissolved gas content relative to the water surface to exceed 110 percent of saturation.

(s) Bioassay median tolerance concentrations are to be based on latest available research results for the materials, by bioassay tests procedures for simulating actual stream conditions as set forth in the latest edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association, or in accordance with tests or analytical procedures that have been found to be equal or more applicable by EPA. Bioassay studies are to be made using the most sensitive local species and life stages of economic or ecological importance; provided other species whose relative sensitivity is known may be used when there is difficulty in providing the most sensitive species in sufficient numbers.

When specific application factors are not available, the factor is to be determined by using methods listed in Water Quality Criteria published by the Federal Water Pollution Control Administration (1968), or by using other methods accepted as equal or applicable by EPA.

(t) Metal limits for the Clark Fork River (mainstem) from the confluence of Warm Springs Creek to the confluence with Cottonwood Creek are:

Material	Average Daily Concentration ug/l	Maximum Instantaneous Concentration ug/l
Total copper	90	180
Dissolved copper	30	40
Total zinc	300	1,000
Dissolved zinc	80	140
Total iron	1,300	2,200
Dissolved iron	150	160
Total lead	100	100
Dissolved lead	100	100
Total cadmium	10	10
Total arsenic	10	16
Total mercury	1	1

Metal limits for Clark Fork River (mainstem) from the confluence of Cottonwood Creek to the Idaho state line are:

Material	Average Daily Concentration ug/l	Maximum Instantaneous Concentration ug/l
Total copper	50	90
Dissolved copper	30	30
Total zinc	100	200
Dissolved zinc	70	80
Total iron	300	1,300
Dissolved iron	150	150
Total lead	50	50
Dissolved lead	50	50
Total cadmium	10	10
Total arsenic	10	10
Total mercury	1	1

(History: Sec. 69-4814, R.C.M. 1947; IMP Sec. 69-4808.2(1)(b), R.C.M. 1947; Order MAC No. 16-1; Adp. 12/31/72; Eff. 12/31/72; AMD, MAC Notice No. 16-2-3, Order MAC No. 16-2-5; Adp. 7/13/73; Eff. 11/4/73; PRIOR p. 16-375; AMD, MAC Notice No. 16-2-31; Order MAC No. 16-2-11; Adp. 7/19/74; Eff. 9/5/74; PRIOR p. 16-387, 391, 393, 393.1, 393.4.).

APPENDIX C

GLOSSARY

Symbol	Definition
BOD_5	Five-day biochemical demand
cfs	Cubic feet per second
gpcd	Gallons per capita per day
gpd	Gallons per day
gpm	Gallons per minute
JTU	Jackson turbidity unit
lbs/capita/day	Pounds per capita per day
lbs/day	Pounds per day
ml	Milliliter
mgd	Million gallons per day
mg/l	Milligrams per liter
sq. ft.	Square feet
TR	Total recoverable
tpd	Tons per day
μmhos	Micromhos per centimeter
$<$	Less than
$\leq$	Less than or equal to
$\geq$	Greater than or equal to
$\sim$	Approximately
BPT	Best practical treatment
WQB	Montana Department of Health & Environmental Sciences, Environmental Sciences Division, Water Quality Bureau
F & G	Fish and Game, Montana Department of
MDHES	Montana Department of Health & Environmental Sciences
MPDES	Montana Pollutant Discharge Elimination System
NPDES	National Pollutant Discharge Elimination System
BuRec	Bureau of Reclamation
EPA	U. S. Environmental Protection Agency
NOAA	National Oceanographic and Atmospheric Administration
SCS	U. S. Department of Agriculture, Soil Conservation Service.
USGS	U. S. Geological Survey
USPHS	U. S. Public Health Service

APPENDIX D

TABLE OF DISCHARGE PERMITS AND COMPLIANCE SCHEDULES

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
Billings Wastewater Treatment Plant, Billings, MT	MT-0022586	10/30/74	3/31/77	Yes, ST by 3/31/76	01N 26E 26BB
Billings Water Treatment Plant, Billings, MT	MT-0000973	4/30/74	12/31/76	Yes, BPCT by 7/1/76	01S 26E 02D
Laurel Wastewater Treatment Plant, Laurel, MT	MT-0020311	9/16/74	6/30/79	Yes, ST by 7/1/77	02S 24E 15DD
Laurel Water Treatment Plant, Laurel, MT	MT-0000906	3/30/74	12/31/76	Yes, BPCT by 7/1/77	02S 24E 15C
Edgar Sewage Lagoon, Edgar, MT	No Permit	-------	--------	------------------	04S 23E 23D
Fromberg Sewage Lagoon, Fromberg, MT	MT-0021466	9/16/74	6/30/79	Yes, ST by 7/1/77	05S 23E 16C
Bridger Sewage Lagoon, Bridger, MT	MT-0020303	7/24/74	12/31/76	Yes, ST, date not specified	06S 23E 22CB
Belfry Sewage Lagoon, Belfry, MT	MT-0020745	11/21/73	7/1/77	None	08S 22E 10D
Bearcreek Sewage Tank, Bearcreek, MT	MT-0022667	4/3/74	12/31/76	Yes, ST by 7/1/77	08S 21E 04C
Red Lodge Sewage Lagoons, Red Lodge, MT	MT-0020478	2/5/74	12/31/76	None	07S 20E 23

APPENDIX D
(Continued)

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
Roberts Sewage Lagoon, Roberts, MT	MT-002022	4/3/74	12/31/76	Yes, ST by 7/1/77	05S 21E 32
Joliet Sewage Lagoon, Joliet, MT	MT-0020249	11/21/73	7/1/76	None	04S 22E 15
Park City Sewage Lagoon, Park City, MT	MT-0021393	4/3/74	12/31/76	Yes, ST by 7/1/77	02S 23E 34B
Columbus Sewage Lagoon, Columbus, MT	MT-0021580	11/21/73	7/1/77	Yes, ST by 7/1/77	02S 20E 27CB
Absarokee Sewage Lagoon, Absarokee, MT	MT-0021750	11/19/73	7/1/77	Yes, ST by 7/1/77	04S 18E 01AB
Yellowstone Boys Ranch Sewage Lagoon, Billings, MT	MT-0020460	9/16/74	12/31/76	Yes, ST by 7/1/77	01S 25E 19
Big Timber Sewage Lagoon, Big Timber, MT	MT-0020753	2/26/74	12/31/76	Yes, ST by 7/1/77	01N 14E 14AB
Livingston Wastewater Treatment Plant, Livingston, MT	MT-0020435	11/21/73	7/1/76	Yes, ST by 7/1/77	02S 10E 07
Livingston Water Treatment Plant, Livingston, MT	No Permit	--------	--------	----------------	02S 09E 24
Gardiner Sewage Lagoon, Gardiner, MT	MT-0022705	3/21/74	12/31/76	None	09S 08E 22BB
Gardiner Water Treatment Plant, Gardiner, MT	MT-0001040	12/13/73	9/30/76	Yes, BPTC by 1/1/76	09S 08E 23D

APPENDIX D
(Continued)

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
Burlington Northern Wash Water Discharge, Livingston, MT	MT-0000388	4/30/74	7/1/77	BPCT 12/15/75	02S 10E 07D
Burlington Northern Storm Water Discharge, Laurel, MT	MT-0000353	4/30/74	6/30/75	Immediate BPCT	02S 24E 15
Cenex Oil Refinery Process Water Discharge, Laurel, MT	MT-0000264	8/10/73	7/1/76	Yes, BPCT by 1/1/74	02S 24E 15
Montana Power Company Thermal and Ash Pond Discharge, Billings, MT	MT-0000396	7/24/74	6/30/76	Yes, BPTC by 6/30/76	01S 26E 02
Great Western Sugar Company Condenser Water and Process Water Discharge, Billings, MT	MT-0000281	11/1/74	3/31/79	None	01S 26E 10B
Conoco Oil Refinery Process Water Discharge, Billings, MT	MT-0000256	8/10/73	7/1/76	Yes, BPTC by 7/1/77	01S 26E 02B
Exxon Oil Refinery Thermal and Process Water Discharge, Billings, MT	MT-0000477	8/10/73	7/1/76	Yes, BPTC by 7/1/76	01N 26E 24
Montana Sulfur and Chemical Co. Thermal Discharge, Billings, MT	MT-0000230	3/18/74	12/31/76	Yes, BPCT by	1N 26E 25A
Empire Sand and Gravel Wash Water Discharge, Billings, MT	MT-0023515	12/4/74	6/30/77	Immediate BPCT	01N 26E 12D

APPENDIX D
(Continued)

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
Bluewater Fish Hatchery, Fromberg, MT	MT-0001015	No Permit Issued	6/30/77	Yes, BPCT by 7/1/77	06S 24E 09
Canyon Creek Ditch Company, Billings, MT	MT-0022861	Currently under review---------------------			***
Billings Bench Water Association, Billings, MT	MT-0022837	Currently under review---------------------			***
Carl Johnson Feedlot, Billings, MT	F-28-B	11/26/73	11/26/78	None	02N 27E 32DD
Jamartom Ranches, Inc. Big Timber, MT	F-30-B	12/5/73	12/5/78	None	03N 15E 19D
Fred Zeiler Feedlot, Laurel, MT	F-14-B	6/21/73	6/21/78	None	01S 25E 28B
Bangert Feedlot, Belfry, MT	F-20-B	8/28/73	8/28/78	None	08S 22E 15BC
Ray Zeiler Feedlot, Billings, MT	F-24-B	9/13/73	9/13/78	None	01S 26E 18DA
Dave Shaules Feedlot, Billings, MT	MT-0029004	5/24/73	3/31/79	None	02N 27E 32DD
Hindman Hog Company, Fromberg, MT	MT-0029011	7/3/74	6/1/79	None	05S 27E 20DB
Gilbert Amen Animal Confinement, Billings, MT	MT-0029012	7/10/74	6/1/79	None	01S 25E 10DC
Larry Staley Confined Feeding Facility, Billings, MT	MT-0029013	7/17/74	6/1/79	None	01S 25E 18CC

APPENDIX D
(Continued)

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
James L. Baker Confined Swine Operation, Park City, MT	MT-0029016	7/30/74	6/1/79	None	02S 23E 28BB
Weber and Sons Confined Feeding Operation, Laurel, MT	MT-0029022	10/16/74	9/1/79	None	01S 26E 19AB
Eben Huntington Confined Swine Operation, Billings, MT	MT-0029027	10/30/74	10/1/79	None	01S 27E 10C
Carbon County Cattle Company Confined Feeding Operation, Boyd, MT	MT-0022187	8/12/74	3/31/77	None	04S 21E 24B
Patton-Davidson Cattle Feeders Confined Feeding Operation, Park City, MT	MT-0023299	10/30/74	7/1/79	None	03S 22E 07A (03S 22E 08B)
Peavey Montana Feedlot (Peavey Company) Confined Feeding Operation, Laurel, MT	MT-0023442	12/13/74	7/1/79	None	02S 24E 01A
Earl R. Spancer Feedlot Confined Feeding Operation, Fromberg, MT	MT-0022624	10/30/74	7/1/79	None	05S 23E 16CB
Vale Creek Ranch Confined Feeding Operation, Billings, MT	MT-0022292	8/12/74	3/31/77	None	02S 26E 02C
Weschenfelder Feedlot (East Lot) Confined Feeding Operation, Park City, MT	MT-0023507	9/17/74	6/1/79	None	02S 23E 21DC

APPENDIX D
(Continued)

FACILITY	NPDES OR MPDES PERMIT NO.	DATE ISSUED	EXPIRATION DATE	COMPLIANCE SCHEDULE*	LOCATION**
Weschenfelder Feedlot (Main Lot) Confined Feeding Operation, Park City, MT	MT-0023493	9/17/74	6/1/79	None	02S 23E 29AB 02S 23E 20DC

* ST = Secondary Treatment; BPCT = Best Practicable Control Technology

** Legal description as township - range - section, and where available in quarter sections (see Appendix A).

*** Location of irrigated acres on file with the Montana Water Quality Bureau, Department of Health and Environmental Sciences, Helena 59601.

UPPER YELLOWSTONE RIVER BASIN

PLATE - I